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Full-Scale Field Evaluation of Waste Disposal from Coal-Fired Electric Generating Plants
Volume 4. Appendices C through E

Little (Arthur D.), Inc., Cambridge, MA

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Volume IV. Appendices C Through E

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16. ABSTRACT

The six-volume report summarizes results of a 3-year study of current coal ash and flue gas desulfurization (FGD) waste disposal practices at coal-fired electric generating plants. The study involved characterization of wastes, environmental data gathering, evaluation of environmental effects, and engineering/cost evaluations of disposal practices at six sites around the country. Study results provide technical background data and information for EPA, state and local permitting officials, and the utility industry for implementing environmentally sound disposal practices. Study data suggest that no environmental effects have occurred at any of the six sites; i.e., data from wells downgradient of the disposal sites indicate that waste leachate has resulted in concentrations of chemicals less than the EPA primary drinking water standards. A generic environmental evaluation--based on a matrix of four waste types, three disposal methods, and five environmental settings--shows that, on balance, technology exists for environmentally sound disposal of coal ash and FGD wastes for ponding, interim ponding/landfilling, and landfilling. For some combinations of waste types, disposal methods, and environmental settings, mitigation methods must be taken to avoid adverse environmental effects. Costs of waste disposal operations are highly system and site specific.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Ashes	Pollution Control	13B	21B
Waste Disposal	Flue Gases	Stationary Sources		
Wastes	Desulfurization		14G	07A, 07D
Coal	Cost Engineering		21D	14A
Combustion				
Electric Power Plants			10B	

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This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

This report summarizes results of a 3-year study of current coal ash and flue gas desulfurization (FGD) waste disposal practices at coal-fired electric generating plants. The study was conducted by Arthur D. Little, Inc., under EPA contract 68-02-3167, and involved characterizing wastes, gathering environmental data, assessing environmental effects, and evaluating the engineering/costs of disposal practices at six selected sites in various locations around the country. Results of the study are providing technical background data and information to EPA, State and local permitting officials, and the utility industry for implementing environmentally sound disposal practices.

Data from the study suggest that no major environmental effects have occurred at any of the six sites. For example, data from wells downgradient of the disposal sites indicate that the contribution of waste leachate to the groundwater has generally resulted in concentrations of chemicals less than the primary drinking water standards established by EPA. Although occasional exceedances of the standards were observed, these were not necessarily attributable to coal ash and FGD waste. A generic environmental evaluation based on a matrix of four waste types, three disposal methods, and five environmental settings (based on climate and hydrogeology) shows that technology exists for environmentally sound disposal of coal ash and FGD wastes for ponding, interim ponding/landfilling, and landfilling. For some combinations of waste types, disposal methods, and environmental settings, measures must be taken to avoid adverse environmental effects. However, site-specific application of good engineering design and practices can mitigate most potentially adverse effects of coal ash and FGD waste disposal. Costs of waste disposal operations are highly system- and site-specific.

APPENDIX C

SAMPLING AND ANALYSIS PROCEDURES MANUAL

FULL-SCALE FIELD EVALUATION OF WASTE DISPOSAL FROM COAL-FIRED ELECTRIC GENERATING PLANTS

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EPA Contract 68-02-3167

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PREFACE

This manual establishes administrative and technical pocedures for conducting field sampling and analysis for selected site investigations relating to U.S. Environmental Protection Agency (EPA) Contract No. 68-02-3167, "Characterization and Environmental Monitoring of Full Scale Utility Waste Disposal Sites" with Arthur D. Little, Inc. of Cambridge, Massachusetts.

This manual, entitled, "Sampling and Analysis Procedures Manual," is one of four manuals which will govern and control the various aspects of field and laboratory testing and analysis for evaluating selected utility waste disposal sites.

Preparation of this manual was primarily the responsibility of Arthur D. Little, Inc., under the overall direction of C.J. Santhanam, Arthur D. Little, Inc. Project Director and Julian W. Jones, EPA Project Officer. The responsible personnel, along with other project team members who contributed by direct input, review, and comment, are:

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ABBREVIATIONS

AA	atomic absorption
AE	atomic emission
ASTM	American Society for Testing and Materials
Btu	British thermal unit
cc	cubic centimeter
cm/sec	centimeter per second
°C	degrees Centigrade
°F	degrees Fahrenheit
EPA	Environmental Protection Agency
ESP	electrostatic precipitator
FGC	flue gas cleaning
FGD	flue gas desulfurization
ft	feet
g	gram
IC	ion chromatography
ICAP	inductively coupled argon plasma
in.	inch
kg	kilogram
L	liter
lb	pound
M	molar
min	minute
mL	milliliter
mm	millimeter
mV	millivolt
N	normal
ppm	parts per million
psi	pounds per square inch
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
sec	second
SPT	standard penetration test
TDS	total dissolved solids
TOS	total oxidizable sulfur

Note: For conversion units, see page C-iv.

CONVERSION FACTORS

English/American Units	Metric Equivalent
Length:	
1 inch	2.540 centimeters
1 foot	0.3048 meters
1 fathom	1.829 meters
1 mile (statute)	1.609 kilometers
1 mile (nautical)	1.852 kilometers
Area:	
1 square foot	0.0929 square meters
1 acre	4,047 square meters
Volume:	
1 cubic foot	28.316 liters
1 cubic yard	0.7646 cubic meters
1 gallon	3.785 liters
1 barrel (42 gals)	0.1589 cubic meters
Weight/Mass:	
1 pound	0.4536 kilograms
1 ton (short)	0.9072 metric tons
Pressure:	
1 atmosphere (normal)	101,325 pascal
1 pound per square inch	0.07031 kilograms per sq. centimeter
1 pound per square inch	6894 pascal
Concentration:	
1 part per million (weight)	1 milligram per 1000 gm
Speed:	
1 knot	1.853 kilometers per hour
Energy/Power:	
1 British thermal unit	1,054.8 joules
1 megawatt	3.600×10^9 joules per hour
1 kilowatt hour	3.60×10^6 joules
Temperature:	
1 degree Fahrenheit	5/9 degree Centigrade

TABLE OF CONTENTS

Page (C-)

PREFACE ii
ABBREVIATIONS iii
CONVERSION FACTORS iv

LIST OF TABLES viii
LIST OF FIGURES ix
Glossary xi
1.0 INTRODUCTION 1.1
- 1.1 OVERALL PROGRAM 1.1
- 1.2 PROJECT APPROACH 1.4
- 1.3 PURPOSE OF THIS MANUAL 1.6
- 1.4 MANUAL ORGANIZATION 1.6

2.0 GENERAL CONSIDERATIONS ON SAMPLING AND ANALYSIS 2.1
- 2.1 OVERVIEW 2.1
- 2.2 TEST PLANS 2.1
- 2.3 PHYSICAL PROPERTIES 2.2
- 2.4 CHEMICAL PROPERTIES 2.5

3.0 RESPONSIBILITY AND INTERFACING 3.1
4.0 SAMPLING METHODOLOGY AND PROCEDURES 4.1
- 4.1 INTRODUCTION 4.1
- 4.2 WET DISPOSAL (PONDING) SAMPLING APPROACH 4.2
  - 4.2.1 Introduction 4.2
  - 4.2.2 Sampling of the Contents of the Pond 4.5
  - 4.2.3 Sampling and Flow Measurement for Pond Influents and Non-Point Source Effluents 4.7
  - 4.2.4 Sampling of Pond Effluents (Surface Point Source) 4.11
- 4.3 DRY DISPOSAL (LANDFILLING) SAMPLING APPROACH 4.12
  - 4.3.1 Introduction 4.12
  - 4.3.2 Sampling of the Contents of the Landfill 4.12
  - 4.3.3 Sampling of Landfill Influents 4.15
  - 4.3.4 Sampling of Landfill Runoff 4.17
- 4.4 SOIL SAMPLING APPROACH 4.17
- 4.5 GROUNDWATER SAMPLING APPROACH 4.18
  - 4.5.1 Introduction 4.18
  - 4.5.2 Sampling Methods 4.19
  - 4.5.3 Special Precautions 4.22
- 4.6 SURFACE WATERS SAMPLING APPROACH 4.23
- 4.7 FIELD MEASUREMENTS 4.27
- 4.8 SAMPLE CONTAINERS 4.27
- 4.9 EQUIPMENT AND CONTAINER CLEANING 4.28
- 4.10 FILTERING AND PRESERVATION OF SAMPLES 4.29
- 4.11 FIELD DOCUMENTATION 4.30
  - 4.11.1 Labels 4.30
  - 4.11.2 Field Notebooks 4.32
  - 4.11.3 Chain-of-Custody Procedures 4.33
- 4.12 SHIPMENT OF SAMPLES 4.33
- 4.13 TERMINATION OF THE SAMPLING/ANALYSIS PROGRAM 4.34

TABLE OF CONTENTS (Continued)

Page (C-)

5.0 PREPARATION OF SAMPLES FOR ANALYSIS 5.1
  5.1 ALIQUOTING AND COMPOSITING OF SOLUTIONS, SLURRIES, AND SOLIDS FOR CHEMICAL ANALYSIS 5.1
    5.1.1 Solutions 5.1
    5.1.2 Slurries 5.4
    5.1.3 Solids 5.5
  5.2 DRYING OF SAMPLES 5.5
  5.3 SEPARATION OF SOLID AND LIQUID PHASES 5.6
  5.4 DIGESTION AND PREPARATION PROCEDURES 5.6
6.0 PHYSICAL LABORATORY TESTING PROCEDURES 6.1
  6.1 INTRODUCTION 6.1
  6.2 PHYSICAL LABORATORY TESTING PROCEDURES 6.4
    6.2.1 Natural Moisture Content Determinations 6.4
    6.2.2 Index Tests 6.5
    6.2.3 Compaction Tests 6.6
    6.2.4 Strength Tests 6.6
    6.2.5 Permeability Tests 6.7
7.0 CHEMICAL LABORATORY TESTS 7.1
  7.1 INTRODUCTION 7.1
  7.2 INDUCTIVELY COUPLED ARGON PLASMA (ICAP) 7.13
  7.3 METALS BY ATOMIC ABSORPTION (AA) 7.15
    7.3.1 Arsenic (Hydride Evolution or Graphite Furnace) 7.18
    7.3.2 Selenium (Hydride Evolution and Graphite Furnace) 7.18
    7.3.3 Antimony (Graphite Furnace) 7.20
    7.3.4 Mercury (Cold Vapor) 7.20
    7.3.5 Other Metals by AA 7.20
  7.4 ION CHROMATOGRAPHY (IC) 7.21
  7.5 MISCELLANEOUS ANALYSES BY WET CHEMICAL AND OTHER METHODS 7.23
    7.5.1 Total Oxidizable Sulfur (TOS) 7.23
    7.5.2 Sulfate 7.23
    7.5.3 Carbonate 7.24
    7.5.4 Alkalinity/Acidity 7.24
    7.5.5 Total Dissolved Solids (TOS) 7.24
    7.5.6 Acid Insolubles 7.24
    7.5.7 pH 7.25
    7.5.8 Conductivity 7.25
    7.5.9 Boron/Silicon 7.25
    7.5.10 Fluoride and Chloride 7.25
  7.6 RADIOACTIVITY 7.26
  7.7 ORGANIC ANALYSIS OF FGC WASTES 7.27
  7.8 DOCUMENTATION OF LABORATORY ACTIVITIES 7.29
    7.8.1 Laboratory Chain-of-Custody Procedures 7.29
    7.8.2 Laboratory Log Notebook 7.29

TABLE OF CONTENTS (Continued)

Page (C-)

8.0 QUALITY ASSURANCE/QUALITY CONTROL 8.1
  8.1 OVERVIEW OF QUALITY ASSURANCE/QUALITY CONTROL ACTIVITIES 8.2
    8.1.1 Quality Assurance 8.2
    8.1.2 Quality Control 8.5
  8.2 QUALITY ASSURANCE AND QUALITY CONTROL ACTIVITIES FOR PHYSICAL TESTING 8.9
    8.2.1 Introduction and Summary 8.9
    8.2.2 Responsibilities 8.10
    8.2.3 Administrative QA Activities 8.11
    8.2.4 Technical QA Activities 8.14
    8.2.5 QC Activities 8.17
  8.3 QUALITY ASSURANCE AND QUALITY CONTROL ACTIVITIES FOR CHEMICAL SAMPLING AND ANALYSIS 8.19
    8.3.1 Introduction and Summary 8.19
    8.3.2 Responsibilities 8.19
    8.3.3 Administrative QA Activities 8.20
    8.3.4 Technical QA Activities 8.21
    8.3.5 Quality Control Activities 8.24

REFERENCES R.1
BIBLIOGRAPHY B.1

LIST OF TABLES

Table No.		Page (C-)
1.1	Major Participants: EPA Contract No. 68-02-3167	1.5
2.1	Site-Specific Test Plan — General Outline	2.3
2.2	Site-Specific Test Plan — Sampling & Analysis Detail	2.4
2.3	Proposed Analytes and Analytical Methods	2.7
4.1	Wet Ponding — Typical Wastes and Related Streams	4.5
4.2	Dry Disposal — Typical Wastes and Related Streams	4.14
4.3	Sampling Approaches and Methods for Various Well Parameters	4.20
5.1	Summary of Aliquoting/Compositing Procedures	5.2
5.2	Digestion Procedures for Liquid Samples Metals Analysis	5.8
5.3	Digestion Procedures for FGC Solid and Soil Samples Metals Analysis	5.9
6.1	Dry Landfill Model Site: Typical Physical Testing Quantities	6.2
6.2	Wet Pond Model Site: Typical Physical Testing Quantities	6.3
7.1	Priority Ranking of Chemical Analyses for Liquids	7.9
7.2	Priority Ranking of Chemical Analyses for Solids	7.10
7.3	Ranking of Samples with Regard to Importance of Chemical Analysis	7.11
7.4	Sample Sampling and Analysis Chemical Matrix	7.12
7.5	ICAP Detection Compared with Sample Concentrations and Other Concentrations of Interest	7.14
7.6	Possible Elements Distribution by Analysis	7.17
7.7	Data for Metals that May Require Analysis by a Method Other Than ICAP	7.19
7.8	Comparison of IC Detection Limits with Ranges of Interest	7.22
8.1	QC Samples Required During Field Sampling	8.31

LIST OF FIGURES

Figure No.		Page (C-)
4.1	Wet Disposal (Ponding) Influents and Effluents	4.4
4.2	Dry Disposal (Landfilling) Influents and Surface Effluents	4.13
4.3	Transect and Grid Sampling Schemes	4.25
4.4	Example of Sample Container Label	4.31
7.1	Initial Screening Analyses of Waste Samples	7.2
7.2	Ash Slurry Sample Analysis Scheme	7.3
7.3	Wet FGC Waste Sample Analysis Scheme	7.4
7.4	Soil Sample Analysis Scheme	7.5
7.5	Stabilized FGC Waste Sample Analysis Scheme	7.6
7.6	Groundwater and/or Surface Water Sample Analysis Scheme	7.7
7.7	Dry FGC Waste Sample Analysis Scheme	7.8
7.8	Decision Process for Using ICAP and/or Flame or Flameless AA	7.16
7.9	Summary of Organic Analysis Approach	7.28
8.1	Procedure for Qualifying Groundwater Analytical Procedures	8.27
8.2	Procedure for Qualifying FGC Waste Analytical Procedures (Solid Phase)	8.28
8.3	Procedure for Qualifying FGC Waste Analytical Procedures (Liquid Phase)	8.29

EXHIBITS		Page(C-)
EXHIBIT A.1-1	VARIETY OF ASH AND OTHER WASTE PRODUCED IN COAL COMBUSTION	E.1
EXHIBIT A.5-1	GROUNDWATER SAMPLING BACKGROUND	E.3
EXHIBIT A.7-1	PROCEDURE FOR MEASUREMENT OF GROUNDWATER LEVEL	E.11
EXHIBIT A.8-1	CLEANING OF EQUIPMENT	E.13
EXHIBIT A.11-1	CHAIN-OF-CUSTODY PROCEDURE (FIELD)	E.14
EXHIBIT B.2-1	EFFECT OF DRYING TEMPERATURE ON WATER – CONTENT DETERMINATION OF FGC WASTES	E.16
EXHIBIT B.3-1	PROCEDURE FOR PRESSING LIQUOR FROM FGC AND SOIL SAMPLES	E.18
EXHIBIT B.4-1	DIGESTION AND FUSION PROCEDURES	E.21
EXHIBIT C.2-1	PROCEDURES FOR THE CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST WITH PORE PRESSURE MEASUREMENTS	E.26
EXHIBIT C.2-2	DESCRIPTION FOR EXTENDED PERMEABILITY ANALYSES	E.29
EXHIBIT D.3-1	ATOMIC ABSORPTION SPECTROPHOTOMETRIC DETERMINATION OF ARSENIC BY HYDRIDE GENERATION	E.32
EXHIBIT D.3-2	ATOMIC ABSORPTION SPECTROPHOTOMETRIC DETERMINATION OF SELENIUM BY HYDRIDE GENERATION	E.38
EXHIBIT D.3-3	COMPARISON OF HYDRIDE EVOLUTION AND GRAPHITE FURNACE METHODS FOR ARSENIC, SELENIUM, ANTIMONY, AND MERCURY	E.44
EXHIBIT D.4-1	PROCEDURE FOR OBTAINING ION CHROMATOGRAMS USING THE DIONEX MODEL 14 SYSTEM EQUIPPED WITH A WISP AUTO INJECTOR	E.48
EXHIBIT D.5-1	MEASUREMENT OF pH	E.55
EXHIBIT D.5-2	ANALYSIS OF TOTAL DISSOLVED SOLIDS (TDS)	E.56
EXHIBIT D.5-3	PROCEDURES FOR ANALYSIS OF SULFITE AND TOTAL OXIDIZABLE SULFUR (TOS)	E.58
EXHIBIT D.5-4	MEASUREMENT OF ALKALINITY/ACIDITY	E.64
EXHIBIT D.5-5	PROCEDURES FOR ANALYSIS OF CARBONATE (IN SOLIDS)	E.71
EXHIBIT D.5-6	DETERMINATION OF THE QUANTITY OF ACID INSOLUBLE MATERIAL	E.75
EXHIBIT D.5-7	PROCEDURES FOR SULFATE ($SO_4^{=}$) ANALYSES	E.76
EXHIBIT D.6-1	MEASUREMENT OF RADIOACTIVITY IN VARIOUS SOLID AND LIQUID SAMPLES AND FROM THE SITE	E.79

GLOSSARY

Fixation: The process of putting into a stable or unalterable form.

Impoundment: Reservoir, pond, or area used to retain, confine, or accumulate a fluid material.

Leachate: Soluble constituents removed from a substance by the action of a percolating liquid.

Leaching Agent: A liquid used to percolate through a substance that results in the removal of soluble constituents.

Pozzolan: A siliceous or aluminosiliceous material that in itself possesses little or no cementitious value but that in finely divided form and in the presence of moisture will react with alkali or alkaline earth hydroxide to form compounds possessing cementitious properties.

Pozzolanic Reaction: A reaction producing a pozzolanic product.

Reagent: A substance that takes part in one or more chemical reactions or biological processes and is used to detect other substances.

Stabilization: Making resistant to physical or chemical changes by treatment.

Titer: The strength of a solution or the concentration of a substance in solution as determined by titration.

Titration: A process for determining the strength of a solution or the concentration of a substance in solution in terms of the smallest amount of a reagent of known concentration required to bring about a given effect in reaction with a known volume of the test solution.

1.0 INTRODUCTION

1.1 OVERALL PROGRAM

This Manual is one of the elements of a program undertaken by Arthur D. Little, Inc., as prime contractor for the Environmental Protection Agency (EPA) under EPA Contract No. 68-02-3167 entitled "Characterization and Environmental Monitoring of Full-Scale Utility Waste Disposal Sites." The overall purpose of this program is to obtain data and information concerning the storage, treatment, and disposal of coal ash (fly ash and bottom ash) and FGD waste from coal-fired utility plants. Results of the study will provide the technical background data and information needed to assist the EPA in determining the degree to which the disposal of these wastes needs to be managed in order to protect human health and the environment. The disposal methods examined will include the most prevalent methods used in the industry as well as those that are likely to represent the best control technology for the disposal of coal ash alone, coal ash and FGD waste combined, and, if apppropriate, FGD waste alone.

Since this project is undertaken to support the EPA in its regulatory responsibilities under the Resource Conservation and Recovery Act (RCRA) of 1976, concerning utility solid waste disposal, the highest screening priority is given to three subject areas that are both characteristically important for utility solid waste disposal and principal regulatory responsibilities under RCRA. Using this philosophy, the three high priority subject areas are:

1. **Impact on Groundwater Quality**

   The major impact on groundwater quality is that associated with the movement of leachate from the wastes to the groundwater in the region of disposal. Specifically, this is the highest priority consideration under RCRA. This Sampling and Analysis Procedures Manual is primarily geared to provide information on the physical and chemical nature of the wastes, leachate, and the surrounding soil such that projections on the movement of leachate from the wastes to the groundwater in the region can be made with a reasonable level of confidence. Physical and engineering characterization and chemical analysis are geared towards this end.

In areas where the groundwater is either non-existent or far too distant for the leachate to have made contact with it, the characterization efforts will be made to determine the extent to which the leachate plume has moved and thereby provide data that can be used in assessing potential impacts.

2. **Impact to Surface Water Quality from Non-point Sources**

Impact on surface waters in the vicinity of the disposal site from such waste disposal can occur due to two factors:

^ Surface runoff originating from or passing over the disposal site and into the surface waters, and

^ Leachate from the wastes moving to the groundwater and thereby to the surface waters or alternatively directly moving through the sub-surface to the water body.

It is to be noted that the non-point impact of such solid waste disposal is often more important in those cases where there is no direct effluent overflow from such waste deposits to the surface waters. For example, if an ash pond has a very large overflow to a river, this direct discharge is often much larger in quantity than the total non-point surface runoff and groundwater seepage into the same river. To the extent possible, efforts will be made to determine the impact at non-point sources with the understanding that in some cases it may be difficult, if not impossible, to make a reasonable assessment of non-point impacts.

3. **Use of Potentially Mitigative Design, Management, or Control Practices**

This is an important part of this project. The mitigative control approaches could be one of four kinds:

- Mechanical processing so as to provide less hydraulic head on the waste in the disposal site and hence, minimize leachate movement from the site. Dewatering methods, forced oxidation leading to the production of better FGD wastes for filtration, and several others are illustrative examples of this kind of mitigative practice.
- Use of liners. Lining of a disposal site with bentonite, clay, poz-o-pac and other linings are illustrative examples of this kind. It is to be noted that in some site-specific cases, clay might be an existing sub-surface feature. These natural linings also are important mitigative measures and could be part of appropriate site selection as an engineering practice for waste disposal.
- Minimizing water requirements for handling of the wastes will reduce the total movement of dissolved materials into the surrounding areas. While this is not a direct factor, recycle of ash pond water, for example, tends to reduce the total outflow of pollutants from the disposal of ash.
- Use of stabilization processes. Stabilization of FGD wastes by lime and fly ash or other methods provides a waste that could be deposited and compacted so as to reduce the movement of leachate from it.

The above are illustrative examples of the kind of mitigative practices that will be evaluated in this project. It is to be noted that proper site selection is an extremely important mitigative management practice. The selection of preliminary candidate and back-up sites reflects a broad variety so as to take into account the site selection approaches that have been employed and thereby attempt to bracket the environmental impacts of appropriate site selection.

1.2 PROJECT APPROACH

Functionally, the project has been subdivided into four areas of endeavor:

1. The selection of 12 representative utility waste disposal sites. The selection process will take into account:
    a. Waste type (characteristics) and method of disposal;
    b. Hydrogeologic and geotechnical considerations; and
    c. Environmental considerations.
2. The development of the twelve sites for proper environmental monitoring. This effort will consist of the following:
    a. Hydrogeologic and geotechnical surveys of each site;
    b. Assessment of the environment as it affects waste and host soil sampling-related actions; and
    c. Development of groundwater monitoring wells and field support facilities for sampling and analysis.
3. Sampling and analysis of the waste, groundwater, surface water, and the surrounding soils for the purpose of physical and chemical characterization.
4. Integrated engineering and economic assessment of the various types of waste disposal operations, together with the development of adequate cost data describing a generic variety of waste disposal methods.

The result of these activities will be subject to a fully integrated environmental assessment as well as engineering and economic analysis. The final result will be a set of recommendations on disposal practices.

The project has been divided into three major tasks for obtaining and evaluating information at the sites:

Task I: Preliminary Site Selection and Test Plan

TABLE 1.1

MAJOR PARTICIPANTS: EPA CONTRACT NO. 68-02-3167

Program Area	Principal Participants
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Physical Sampling & Analysis	University of Louisville Louisville, KY 45208 and Bowser-Morner Testing Laboratories, Inc. Dayton, OH 45401
Engineering/Economic Evaluation	Arthur D. Little, Inc. Cambridge, MA 02140 and Kaiser Engineers Power Corp. Oakland, CA 94623
Quality Assurance/Quality Control	Arthur D. Little, Inc. Cambridge, MA 02140

Source: Arthur D. Little, Inc.

Preparation;

Task II: Site Evaluation and Characterization and Environmental Monitoring; and

Task III: Environmental and Economic Assessments.

The prime contractor for this program is Arthur D. Little, Inc., Cambridge, MA. The principal participants in the overall program and their areas of contribution are listed in Table 1.1.

1.3 PURPOSE OF THIS MANUAL

This Appendix B, "Sampling and Analysis Procedures Manual," for utility waste disposal sites is structured to develop information on the current and potential impact on ground and surface water quality and other environmental impacts in the vicinity of the disposal site. The sampling and analysis phase of the program will provide physical, engineering, and chemical characterization of the waste, surrounding soils, and ground and surface waters to satisfy the overall program objectives.

This manual has been prepared to provide a common methodological approach for the conduct of the sampling and analysis phase of this program. The manual will provide guidelines for a common approach and techniques for sampling and analysis and will thus ensure compatible data gathering from different sites, by different subcontractors. For the sampling of physical and geotechnical properties, the manual will provide uniformity in approach and methodology between Bowser-Morner and other drilling contractors who may be utilized.

This manual is also intended to define standard operating procedures and sampling and analysis techniques for use in, or reference by, the site-specific test plans to be prepared later. Where detailed technical procedures from other sources are to be used without modification, they have been included here only by reference. Other procedures which have been modified for the purposes of this program are covered in detail.

1.4 MANUAL ORGANIZATION

This is one of four basic manuals (Appendix A through Appendix D) that will be produced to maintain a common basis for the conduct of this program and to ensure that the project team members conducting various aspects of the field work will do so in an acceptable and cost-effective manner. The project-related subjects for each manual consist of the following:

Appendix A -- Hydrogeologic and Geotechnical Procedures Manual

Appendix B -- Sampling and Analysis Procedures Manual

Appendix C -- Engineering and Economic Evaluation Procedures Manual

Appendix D -- Environmental Assessment Procedures Manual

Details on the engineering practices to develop a site are given in Appendix A, "Hydrogeologic and Geotechnical Procedures Manual." Appendix C, "Engineering and Economic Evaluation Procedures Manual," describes the approach and methodology for performing the engineering and economic assessment of the disposal operation at each site. A later manual, Appendix D, "Environmental Assessment Procedures Manual," will provide the background and approach on how the data gathered by use of procedures described in this manual will be employed for environmental assessment.

This Sampling and Analysis Procedures Manual provides the basis and overall approach for the sampling and analysis tasks in the program. These include:

^ Team responsibilities and coordination. Areas of interaction between subcontractors are broadly outlined.

^ Preparation of the sampling and analysis sections of the site-specific test plans.

^ A generic approach to sampling and analysis of waste sites.

^ Procedures for sampling (for chemical and physical tests).

^ Procedures for analysis (of chemical and physical properties).

^ Procedures for quality assurance and quality control, QA/QC (for physical and chemical sampling and analysis).

2.0 GENERAL CONSIDERATIONS ON SAMPLING AND ANALYSIS

2.1 OVERVIEW

The overall approach to the sampling and analysis portion of the program will involve three major activities:

1. A site-specific detailed test plan will be prepared;
2. Sampling and analysis for physical properties will be performed; and
3. Sampling and analysis for chemical properties will be performed.

As currently envisioned, the site-specific test plans will be prepared as soon as a site is selected and nominated by the Arthur D. Little, Inc. Project Director (after EPA approval). As part of the site selection process, several site visits will have been made, and this information will be included in the test plan. Once the test plan has been accepted by the utility whose site has been selected and EPA, site development will occur. Sampling for physical testing will be done during site development as will any on-site (field) testing for physical properties. Sampling of waste and soils for chemical testing will also occur during site development. Laboratory testing for physical properties will occur during and after site development. Sampling of groundwater, surface waters, runoff, and currently disposed waste for chemical testing will all be done after site development, with sampling extending for a period of about one year. Chemical analysis will be performed shortly after the respective sample has been taken.

2.2 TEST PLANS

Following the nomination of a site by Arthur D. Little, Inc. and approval by EPA, the first task at the site will be the preparation of a site-specific test plan. The test plan will comprise a detailed explanation of all activities to be conducted on a specific site. This will include information on site development, sampling, analysis, engineering/economics, and schedule and cost. To the extent possible, the test plan will refer to the specific procedures outlined in each of the four procedures manuals. Any new or novel procedures to be used at a site that are not detailed in a manual will be explained in the test plan.

A general outline for the test plan is presented in Table 2.1. Inputs on the sampling and analysis aspects will be received from Arthur D. Little, Inc., and where appropriate from TRW and Bowser-Morner, in Sections 3.2, 3.3, 5, and 6 of the test plan. These sections are outlined in more detail in Table 2.2. The sampling portion of the test plan for soils and wastes is included in Appendix A, "Hydrogeologic and Geotechnical Procedures Manual."

Arthur D. Little, Inc. will have the overall responsibility for compiling the test plans.

2.3 PHYSICAL PROPERTIES

Physical property determinations will be made both for the FGC waste deposit and for the surrounding soil. These properties of the waste and soil are useful in evaluating the potential for groundwater pollution. Such data may also be useful in estimating disposal economics of a particular waste disposal site. Permeability, grain size distribution, natural moisture content, and density (void ratio) are useful parameters in indicating the potential for leachate migration of FGC wastes. Grain size, natural moisture content, and other properties identified by field testing of the soil at each site will aid in assessing the potential for groundwater pollution; these tests will also be used in characterizing the groundwater flow regime.

An important aspect in determining the physical engineering characteristics of a waste deposit is the selection of field or laboratory testing conditions. Field testing provides quantitative information on the type and extent of the deposit and can also provide relative density, strength, permeability,

TABLE 2.1

SITE-SPECIFIC TEST PLAN – GENERAL OUTLINE

1. Objectives

2. Background

    2.1 Power Plant and Location
    2.2 Disposal Operation
    2.3 Geotechnical, Hydrologic, Geologic, and Climatologic Baseline
    2.4 Environmental Information

3. Approach

    3.1 Site Development
    3.2 Sampling/On-site Analysis
    3.3 Off-site Analysis
    3.4 Engineering/Economic Data
    3.5 On-site Environmental Data

4. Potential Problems and Alternative Approaches

5. Cost Estimate

6. Schedule

7. Coordination

8. Data Reporting and Handling

Appendices
Drawings

Source: Arthur D. Little, Inc.

TABLE 2.2

SITE-SPECIFIC TEST PLAN — SAMPLING & ANALYSIS DETAIL

3.2 Sampling/On-site Analysis

  3.2.1 Physical Characteristics

    1. Background
    2. Rationale and Quantities
       - Sampling
       - Field Testing

  3.2.2 Chemical Characteristics

    1. Background
    2. Sampling
       - Waste
       - Soil
       - Groundwater
       - Surface Water/Runoff
    3. On-site Measurements

3.3 Off-site Analysis

  3.3.1 Laboratory Testing — Physical

  3.3.2 Laboratory Testing — Chemical

    1. Background
    2. Sample Preparation
    3. Analyses
       - Metals
       - Anions
       - Wet Chemical
       - Organic

Source: Arthur D. Little, Inc.

and compressibility. Laboratory tests performed on disturbed and undisturbed samples are conducted under more controlled conditions and provide more accurate determinations of engineering properties. Since the laboratory tests are performed on relatively small samples, the accuracy of correlating laboratory with field conditions depends on the homogeneity of the waste deposit.

The following field and laboratory tests for physical properties are anticipated for the FGC waste testing program:

Field Tests	**Laboratory Tests**
Vane Shear	Natural Moisture Content
Standard Penetration	Grain Size
Field Permeability	Specific Gravity
Nuclear Depth-Density	Compaction (Proctor)
	Strength
	Permeability
	Compression

Natural moisture content determinations, grain size analyses, and specific gravity determinations will be made in the laboratory from samples obtained during the standard penetration tests. Strength, permeability, and compression testing will be performed on relatively undisturbed thin-walled Shelby tube samples obtained during the field exploration program. The field tests are described in detail in Appendix A, "Hydrogeologic and Geotechnical Procedures Manual." The laboratory testing procedures are described in Section 6 of this Sampling and Analysis Procedures Manual.

2.4 CHEMICAL PROPERTIES

Chemical characterization will be performed on the following materials:

- Previously and freshly disposed FGC wastes;
- Soils from under and around the disposal site;
- Groundwater from existing and/or newly developed groundwater wells; and

- Runoff and/or surface waters from or near the site.

A summary of the analyses and analytical methods to be used for chemical characterization is given in Table 2.3.

In general, initial screening of samples at a site will be made using pH, conductivity, inductively coupled argon plasma (ICAP) and ion chromatography (IC) for liquids, and ICAP for solids. The extent of further more complete analysis and the number of samples analyzed will depend on site-specific factors. The practice of utilizing screening followed by more comprehensive analyses will be used to maximize the amount of information on the elements and species of interest with regard to definition of environmental impact. EPA Level 1 inorganic and organic protocols will be used at two of the sites (one ash and one FGD-containing material).

Detailed chemical analyses will be used to characterize the solid and liquid phases of the wastes according to the priority listing discussed in Section 7. Analytical methods to be used on wastes include IC for anions, atomic absorption (AA) and atomic emission (AE) (inductively coupled- and dc-plasma) for metals, and other wet chemical instrumental and spectrophotometric techniques.

Analysis of groundwater samples will closely parallel the waste analysis. Depending on the data obtained during the initial months of monitoring, the number of analyses may be reduced and the resulting change in effort diverted to analysis of additional samples. Dissolved oxygen and sulfite measurements will be performed to some extent and on sites where FGD materials are currently being disposed and where the waste liquor analyses show the presence of sulfite.

Analysis of soils from under the site and background soil samples from around the site will be performed at some sites. Interstitial pore water analysis or total analysis of the soil will be done to get an indication of contaminant presence. A two-stage analysis will be used to determine which samples will be analyzed comprehensively (similar to the waste and groundwater situation). Selected species such as anions which can be

TABLE 2.3

PROPOSED ANALYTES AND ANALYTICAL METHODS

Analysis Method	Analytes[1]
ICAP – Inductively Coupled Argon Plasma	Ca, Na, Al, Ba, Be, Cu, Fe, F, Mg, Mn, P, Pb, Sr, Ti, V, Zn, Th, Sn, Ag, Co, Cr, Mo, Ni, Zr
AA – Atomic Absorption	As, Se, Sb, Hg, Cd
AE – Atomic Emission (dc-plasma)	B, Si
IC – Ion Chromatography	F^-, Cl^-, NO_3^-, $PO_4^{\equiv}$, $SO_4^{=}$
Instrumental	pH, Conductivity, Radioactivity
Gravimetry	TDS[2], Acid Insolubles
Wet Chemistry	Alkalinity (OH^-), $CO_3^{=}$,TOS[3], $SO_4^{=}$
Spectrophotometry	Trace $SO_3^{=}$
Level 1 Inorganic[3]	Screening for inorganic components
Level 1 Organic[3]	Screening for organic components
Level 2 Organic[3]	Selected organic species analyses, TOC[2], Acid/Base-Neutral extractables
XRD – X-ray Diffraction	Mineral composition for crystalline phases

1. These analytes were selected from the following lists
    - Possible FGC Tracers – Ca, Na, Cl^-, $SO_4^{=}$, pH, $SO_3^{=}$.
    - Proposed interim primary drinking water standards – Ba, Pb, Ag, Cr, As, Se, Hg, Cd, NO_3^-.
    - Proposed secondary drinking water standards – Cu, Fe, Mn, Zn, $SO_4^{=}$, Cl^-, pH.
2. TDS – Total Dissolved Solids
   TOC – Total Organic Carbon
   TOS – Total Oxidizable Sulfur
3. At two sites only.

Source: Arthur D. Little, Inc.

determined by an ion chromatographic scan (F^-, Cl^-, NO^-_3, $SO^=_4$) or those metals which can be determined by ICAP will be used. Whenever these results indicate the presence of leachate, the remainder of the analyses (AA) will be performed.

Surface/runoff water samples will be analyzed for both suspended and dissolved materials. The analysis of suspended materials will involve determination of the relative amount of fly ash and/or FGD material suspended by selective analysis of the solid for metals by ICAP. A similar analysis including ion chromatography of the dissolved species will be performed.

Additional analyses for species not listed may be required during the course of this program at particular sites. Specific EPA-approved analytical methods will be utilized, or others developed, as needed.

3.0 RESPONSIBILITY AND INTERFACING

Sampling and analysis activities will encompass a variety of disciplines and several subcontractors. The major areas of activity will include:

Overall responsibility for sampling and analysis	Arthur D. Little, Inc.
Physical sampling/analysis/QC	Bowser-Morner Testing Laboratories, Inc.
Chemical sampling/analysis/QC	Arthur D. Little, Inc. TRW, Inc.
ICAP analyses	Barringer-Magenta, Ltd.
Advisory QA/QC -- physical sampling/analysis	University of Louisville
QA -- chemical sampling/analysis	Arthur D. Little, Inc.
Overall QA/QC program	Arthur D. Little, Inc.

The interfacing and coordination of activities among the various subcontractors will be an important aspect of the overall program. Briefly, the major responsibilities for interfacing will be as follows:

- The test plan preparation will be under the overall control of Arthur D. Little, Inc. Input on various aspects will be requested of the subcontractors as appropriate.
- Arthur D. Little, Inc. will be responsible for the overall control and management of the program. Any modifications to the test plan approach must be approved by the Arthur D. Little, Inc. Project Director.
- Authorization to proceed with the sampling and analysis program after acceptance of the test plan at a specific site will be given only by the Arthur D. Little, Inc. Project Director.
- The Arthur D. Little, Inc. Project Director will designate a site coordinator for each site who will be responsible for coordinating activities at that site.

The coordinator will be kept informed of all interactions among subcontractors related to sampling and analysis. Interactions between utility and test program personnel on any aspects of the test plan, schedule, etc., will occur through the site coordinator or with his/her prior knowledge.

- A Bowser-Morner site engineer will be responsible for field testing and for obtaining samples of waste and soils during initial development of each site for subsequent physical and chemical tests. Field exploration of the FGC wastes will be performed by either Bowser-Morner personnel or subcontracted personnel under the direction of the Bowser-Morner site engineer. The sampling and analysis program for each site will follow the specific procedure as described in Section 3 of the preliminary test plan. Deviations from the test plan may be necessitated by site-specific conditions and may be made by the site engineer. The Arthur D. Little, Inc. site coordinator and the University of Louisville will review any major changes in the locations or types of samples.
- The Bowser-Morner site engineer and project engineer may modify the physical testing program from the preliminary plan if necessitated by site-specific conditions. They will, however, advise University of Louisville personnel of any such proposed changes prior to implementation.
- The Bowser-Morner physical testing procedures will be approved by University of Louisville personnel prior to the initiation of the testing program. Approximately 1 in every 20 waste samples will be sent to the University of Louisville for comparative strength and permeability testing.
- Sampling of groundwater, surface waters, runoff waters, and freshly produced waste will be performed by the chemical sampling and analysis team (either Arthur D. Little, Inc. or TRW), assigned to the particular site.

Each sampling team will have a team leader who will be responsible for all aspects of the team's performance while in the field, subject to the overall direction of the site coordinator.

- Samples will be obtained from each site according to protocols set forth in the site test plan. Because of site-specific conditions the sampling team leader may determine that alternate procedures may need to be used. However, any such changes must be approved by the site coordinator and the manager of chemical QA prior to implementation.
- Chemical analyses of samples will be performed by Arthur D. Little, Inc. or TRW, depending on the organization responsible for the site. Analyses for trace metals by ICAP will be performed by Barringer-Magenta, Ltd. Each of these three organizations will designate a laboratory coordinator who will be responsible for all analytical activities which take place in his organization. All analyses will be performed according to the procedures set forth in this manual. From time to time, difficulties may be encountered which necessitate procedural changes. All such changes must be approved by the Arthur D. Little, Inc. laboratory coordinator and the manager of QA for chemical sampling and analysis prior to implementation.
- The overall responsibility for quality assurance (QA) and quality control (QC) rests with the Arthur D. Little Project Director.
- Responsibility for program-wide chemical sampling and analysis QA/QC activities rests with the Arthur D. Little, Inc. manager of chemical QA. University of Louisville personnel as advisors to Arthur D. Little, Inc. will provide QA/QC oversight for physical sampling and testing, and will report their findings and recommendations to the Arthur D. Little, Inc. Project Director.

- QC activities related to field testing or sample acquisition will be the responsibility of the designated site engineer (Bowser-Morner) or field team leader (Arthur D. Little, Inc. or TRW), depending upon the performing organization. These designated individuals will be responsible to the QA manager (physical testing or chemical sampling and analysis).
- QC activities relating to laboratory testing and anlaysis will be the responsibility of the designated laboratory coordinator, and these individuals will be responsible to the cognizant QA manager for chemical or for physical testing.

4.0 SAMPLING METHODOLOGY AND PROCEDURES

4.1 INTRODUCTION

The sampling procedures which are described in this section will be used to obtain representative samples of soils, waste, waste site influents and effluents, groundwater, and surface water for chemical characterization and samples of soils and wastes for physical characterization. Also discussed are many of the procedures which are part of the total sampling process, including field measurements, containers, cleaning of equipment for sampling, field documentation, preservation of samples, and shipment of samples. The selection of detailed procedures which will be used at a particular site and the choice of sampling location will be made during preliminary visits to the site and during the development of detailed test plans.

In obtaining samples for both physical and chemical tests, close attention will be given to maintaining their physical and/or chemical integrity. Many of the laboratory tests for physical properties will require discrete samples which are obtained under undisturbed conditions. For these tests the physical integrity of the sample must be maintained during acquisition and transport. Samples for chemical analysis generally do not need to be physically intact but must remain chemically unmodified.

Samples may be composited to provide a single average value, or discrete samples may be taken to provide a range of compositional values. The latter approach will afford a measure of compositional differences which may occur because of time effects, varying fill composition, and other site variables. Where possible, samples for physical and chemical tests will be taken from locations in close proximity in order to provide for maximum correlation with physical properties.

An effort will be made to minimize contamination in obtaining samples for chemical analysis. For example, fly ash is ubiquitous at most sites and could be introduced into samples and sampling points (i.e., wells). In addition, where possible, sample modification such as that which may occur when a liquid sample is taken from an anaerobic condition and then exposed to oxygen will be minimized.

The sampling techniques (e.g., pumping and dipping) used for liquids and well-stirred slurries are very different from those used for solids (e.g., coring). Thus, the physical properties of the material being sampled (e.g., liquid, slurry, or solid) determine the techniques to be used at a specific site. The methodology which may be applicable to wet disposal sites (i.e., ponds) discussed in Section 4.2 will be different from that for dry disposal sites (landfills) discussed in Section 4.3. Sampling methods for soil and groundwater are common to both types of disposal sites and are presented in Sections 4.4 and 4.5. Sampling techniques for surface water are discussed in Section. 4.6.

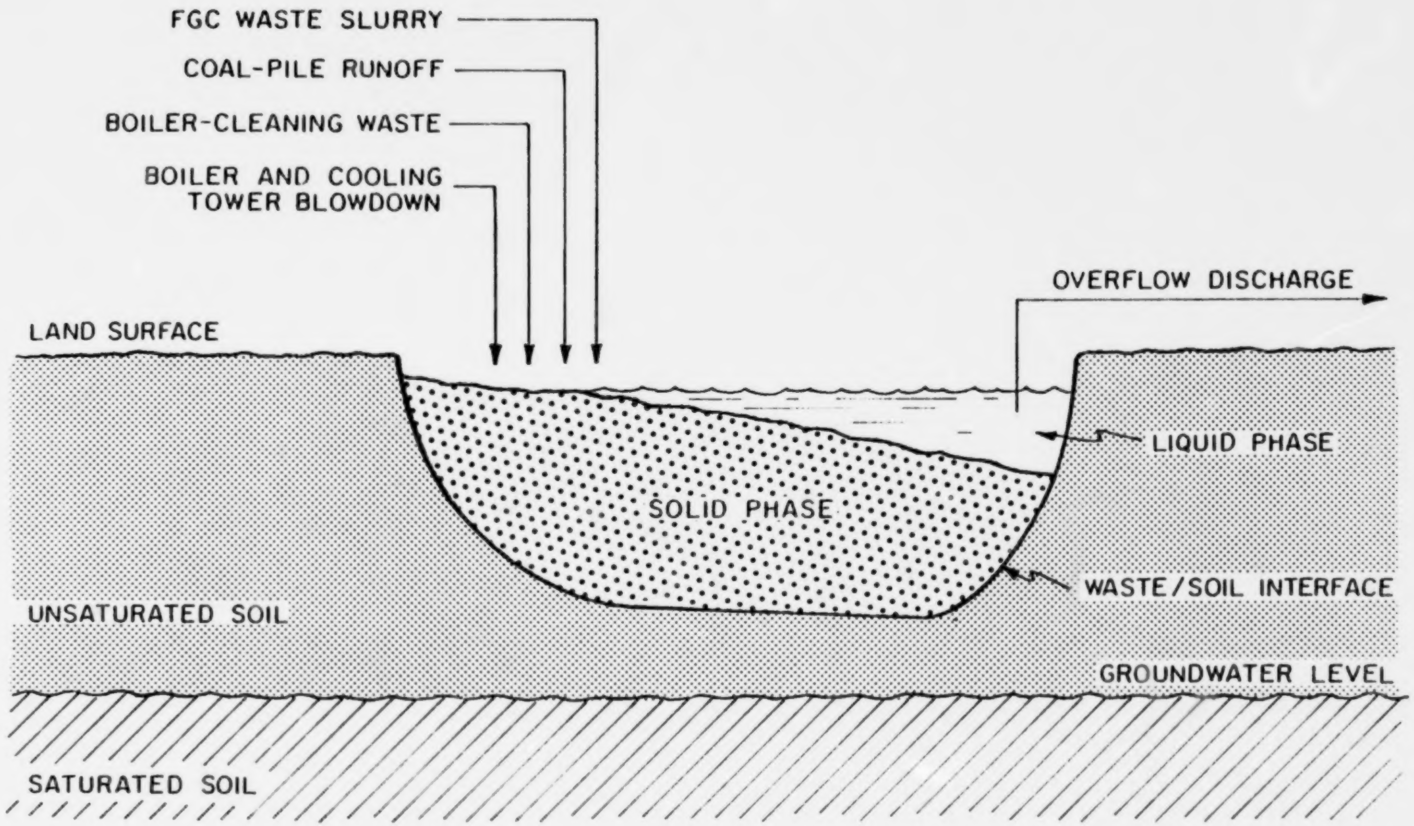
If the utility at the specific site desires to retain a portion of samples obtained, EPA and Arthur D. Little will interact with the utility on the issues to attempt to arrive at solutions.

4.2 WET DISPOSAL (PONDING) SAMPLING APPROACH

4.2.1 Introduction

Information about the various types of influents to, effluents from, and waste present in the pond needs to be obtained in assessing wet disposal (ponding) of FGC wastes. These materials (shown in Figure 4.1) differ in chemical and physical properties as well as in their mode of transport and regularity of flow. (See Table 4.1.) Materials that may enter the pond include slurries of FGC waste (i.e., fly ash, bottom ash, and/or FGD solids) and other wastes that occur from the coal combustion process (e.g., boiler-cleaning wastes, cooling tower blowdown, and runoff from the coal pile).

The chemical and physical properties of these streams may


FGC WASTE SLURRY
COAL-PILE RUNOFF
BOILER-CLEANING WASTE
BOILER AND COOLING TOWER BLOWDOWN
OVERFLOW DISCHARGE
LAND SURFACE
LIQUID PHASE
SOLID PHASE
WASTE/SOIL INTERFACE
UNSATURATED SOIL
GROUNDWATER LEVEL
SATURATED SOIL

Source: Arthur D. Little, Inc.

FIGURE 4.1 WET DISPOSAL (PONDING) INFLUENTS AND EFFLUENTS

TABLE 4.1

WET PONDING – TYPICAL WASTES AND RELATED STREAMS[1]

Name	Physical Characteristics (quantity of suspended solids)	Usual Mode of Transport	Flow Characteristics
Influents:			
Coal-Pile Runoff	low	pipe or ditch	sporadic
Boiler-Cleaning Wastes	low	pipe or ditch	sporadic
Cooling Tower Blowdown and Others	low	pipe or ditch	continuous
Miscellaneous Plant Wastewater	low	pipe or ditch	variable
FGC Waste[2]	low to high	pipe or ditch	
Pond Contents:			
Liquid Supernate	very low	N/A	N/A
Settled Solids	very high	N/A	N/A
Effluents:[3]			
Pond Overflow	low	weir/pipe	continuous

N/A = Not Applicable.

1. For illustration purposes only. Not all influents may be present at all wet disposal sites.
2. FGC waste sluice streams may contain FGD material, a variety of ashes (bottom, economizer, air preheater, fly), mill rejects, and soot.
3. Underground effluents (e.g., leachate occurring by infiltration) are not included since these are not directly able to be sampled.

Source: Arthur D. Little, Inc.

also vary substantially with time. Ash sluice lines may contain mixtures of ash and waste from a variety of sources in the combustion process added at different times. These include mill rejects from pulverization of the coal, bottom ash, economizer ash, air preheater ash, soot, and ESP ash (Exhibit A.1.1). The flow of the sluice line may be continuous, but its composition (e.g., suspended solids) may vary a great deal with time.

The flow of coal-pile runoff is related to precipitation or thawing events and thus is non-continuous and sporadic. Boiler-cleaning waste inflow may occur less frequently than coal-pile runoff, but is more predictable because it is a scheduled event. Cooling tower blowdown waste and pond overflow are generally more continuous streams.

The content of the pond varies in composition from a liquid, low in suspended solids, to an inhomogeneous water-saturated solid. The velocity of the liquid phase is generally quite low compared to other streams.

4.2.2 Sampling of the Contents of the Pond

Sampling of the pond contents will be performed to chemically characterize the liquid phase and to physically and chemically characterize the solid phase. These sampling activities will be carried out during site development and in conjunction with performance of field testing for physical properties.

The approach for obtaining samples for chemical and physical properties of the solid phase will involve use of conventional drilling and coring techniques. (See Appendix A, "Hydrogeologic and Geotechnical Procedures Manual.") A rig will be floated on the pond, anchored, and a 10-cm (4-in.) diameter casing will be driven down to the desired depth. Where possible, the liquid layer inside the casing will be pumped out and samples taken with thin-walled Shelby tubes (ASTM D 1587, Ref. 4.1), a piston sampler (ASTM D 1587, Ref. 4.1), or a split-spoon sampler (ASTM D 1586, Ref. 4.2). These samplers will be made of non-corroding steel and cleaned as specified in Section 5. No grease may be used on any of the samplers used for chemical property samples. Samples at various depths will be obtained by drilling with a side-discharge bit and continually removing the waste to the desired depth, using, where possible, water of known chemical composition or a compressed gas. If appropriate, an inert gas (e.g., nitrogen) will be used to flush the casing prior to sampling material from an environment which is thought to be anaerobic. Where removal of the water from the casing is not feasible, the drilling fluid will be flushed out with pre-analyzed fresh water and samples of waste taken through the standing water.

An average of 18 samples located within the pond is anticipated. These would generally be comprised of six portions obtained at different depths from three boreholes as arbitrarily derived in Appendix A, "Hydrogeologic and Geotechnical Procedures Manual." Deviation from this average number of samples may be made depending on the nature and complexity of the site.

Sampling will occur in conjunction with performance of standard penetration tests (Appendix A). Standard penetration resistance (SPT) tests will be performed on continuous intervals of 0.45 m (1.5 ft) for thin waste deposits of less then 3.05 m (10 ft); on 0.76-m (2.5-ft) intervals for moderately thick waste deposits of 3.05 to 6.1 m (10 to 20 ft); and 1.5-m (5-ft) intervals for thicker deposits.

Piston or Shelby tube samples will generally be used for both physical and chemical laboratory testing and analyses, as they afford minimum disturbance of the sample and minimum exposure to air. Where possible a 3-foot Shelby tube will be obtained for each chemical sample point. A minimum of 0.45 m (1.5 ft) will be obtained for chemical tests. It is anticipated that the number of samples obtained will be proportional to the number of varieties of waste materials encountered. As an example, approximately three to six tube samples or more will be obtained for the physical laboratory testing. The additional Shelby tubes will be obtained for chemical testing and analyses.

Sampling of the liquid phase of the pond will occur during and after site development. Conventional dipping samples and/or capped containers (Ref. 4.3) will be used.

4.2.3 Sampling and Flow Measurement for Pond Influents and Non-point Source Effluents

4.2.3.1 Sampling

Sampling of liquid and slurry influents (Table 4.1) to the pond will involve obtaining samples for chemical analysis and measurement of the mass flow rate of each stream. The term "slurry" can be used to describe most of the influent streams since they will range from blowdown containing few suspended solids to thickened-FGD underflow with 30-40% suspended solids which is pumped as a mud-like material.

The major consideration in designing sampling and flow measurement procedures for slurries is ensuring that the proportion of solids collected is representative of the total stream. It is expected that heterogeneity develops in these streams due to settlement of solids once the turbulence and mixing in the stream decreases. No general sampling technique can guarantee representativeness for all slurry samples which will be encountered in FGC disposal sites. The detailed methodology and procedures will be established for each site using the guidelines given below.

Slurry sampling will be carried out at a point where mixing (stream turbulence) is maximal in order to afford the best opportunity to obtain a relatively complete representation of the stream composition. In situations where the composition may vary widely because of fluctuations in input streams, samples will be taken at appropriate intervals over the sampling time period. The intervals will vary on a site-specific basis, however, at an average site, slurry streams (ash, FGD) will be sampled at least six times over each single sampling period (day).

Samples will be taken using a dipping sampler or capped container which can be opened under the surface of the slurry stream. Horizontal and vertical cross-section samples will be taken during the first time each stream is sampled in order to establish the extent of homogeneity of the cross section. After the level of suspended solids in each sub-sample has been compared, the sub-samples will be composited into a single sample.

When a sampling point is shown to be spatially homogeneous, the number of sub-samples and sampling effort may be reduced.

Automatic samplers may be used for some sites to obtain samples from streams such as ash sluice lines, runoff, or surface waters. However, it will be necessary to prove that the slurry composition is not changed by the delays in transporting the physical sample to the storage containers.

Obtaining representative samples from continuous streams which do not vary greatly in composition or flow rate is easier than sampling sporadic events which vary greatly in both regards. In the former case, a series of grab samples taken at arbitrary times is sufficient to represent the stream. In sporadic situations, modifications may be necessary.

Runoff, as from a coal pile, is one of the least continuous and most unpredictable influents to a pond. Such runoff waters result from precipitation events including both rainstorms and the melting of snow and ice. The composition of runoff liquors, both in terms of suspended and dissolved materials, will be highly dependent on the intensity and duration of the storm event, the nature of the materials which are impacted by these events, and the surface topography of the area itself. The objectives of the runoff sampling program will be to obtain approximate estimates of volume flows and chemical composition of runoff liquors which result from one or more storm events at each site, where such sampling is appropriate. Measurement of volume flows and chemical composition of runoff liquors will lead to very rough estimates since both the flow and composition are extremely variable during the event and are a result of great variability between rain or thaw events. Sampling and analysis at a limited number of events thus can only lead to a limited representation of this phenomenon.

The approach which will be taken for runoff sampling and flow measurement will depend greatly on the extent to which runoff waters are diverted and/or channeled at a particular site. At those sites where runoff enters the pond in defined channels, flow measurement and sampling efforts will resemble those employed for streams or ditches. Either manual methods or automated devices will be used for both efforts. Samples obtained manually will be retained separately and composited as necessary. Automatic devices may lead to obtaining a single grab sample or composition of many grab samples.

Manual sampling requires manpower on-site during runoff events and will be generally used only if local utility personnel are willing to help in the effort by obtaining the samples and automatic sampling is not feasible. Runoff can be sampled by using automatic samplers (Ref. 4.4) which collect either discrete or composited samples in proportion to stream flow. Both battery-powered and ac-powered devices are available. Some devices also include automatic sensing mechanisms which activate the device at the onset of precipitation or runoff flow and deactivate when some minimal condition is reached. If runoff is collected in a holding pond and subsequently pumped to the final disposal pond, the holding pond may be manually sampled in the time frame surrounding an event.

In cases where an event (e.g., boiler cleaning) does not occur at all during the sampling period, no samples can be obtained; and estimates of composition and amounts of influent materials will be obtained and calculated from other available data.

4.2.3.2 Flow Estimates

Estimates of flow will be made using manual or automatic field volume measurements and/or mathematical estimation techniques.

Flow measurement by field tests will involve either total collection or estimates from hydraulic properties (Ref. 4.5). Total collection involves measuring the time required to fill a container of known volume where the entire flow (or an accurately determined fraction of the total) is diverted into the container. Hydraulic property estimates make use of calibrated channels (e.g., flumes and weirs) whose flow properties are known or are accurately predictable from theoretial or empirical relations. Other hydraulic property techniques include measurement of cross-sectional area/depth and linear velocity. Of these approaches, the calibrated flume/weir will afford the most accurate measurements of flow, while the velocity/depth-of-flow approach will provide somewhat less accurate estimates. Field flow measurements may also be made automatically using a continuous automated level recorder in conjunction with a flume or weir. The device can be activated at the onset of precipitation or flow. Use of such a device (for example, the Manning Dipper or Isco Bubbler) together with a flume/weir channel has been found by Arthur D. Little, Inc. to produce acceptable data for measurements in small open channels similar to some which are expected at FGC waste sites.

The number of points at which flow measurement will be required will be determined by the nature of the carrying system (i.e., pipes, open channels, closed culverts) and the complexity of influent streams. For automatic measurements and sampling the devices must be installed or be in place prior to the onset of the event; individual devices will be required for each flow path which is to be monitored. Routine checking or monitoring of the installed flow measurement devices will be performed.

Mathematical estimation involves computation of flow volumes based upon the area of interest. For example, runoff volume may be estimated from the rainfall amounts and known surface dimensions of the waste area. Parameters such as infiltration rate may be subject to uncertainty; however, the precipitation data and area data needed for input into such models can be obtained with a reasonable degree of confidence.

4.2.4 Sampling of Pond Effluents (Surface Point Source)

Pond effluents such as pond overflows which are point source discharges may be sampled using the sampling methodology and approach (including flow measurements) described in the previous section. These streams are generally continuous and low in suspended solids and thus present little difficulty for designing procedures for sampling and flow measurements. Most effluents go over a weir so flow can be determined hydraulically.

4.3 DRY DISPOSAL (LANDFILLING) SAMPLING APPROACH

4.3.1 Introduction

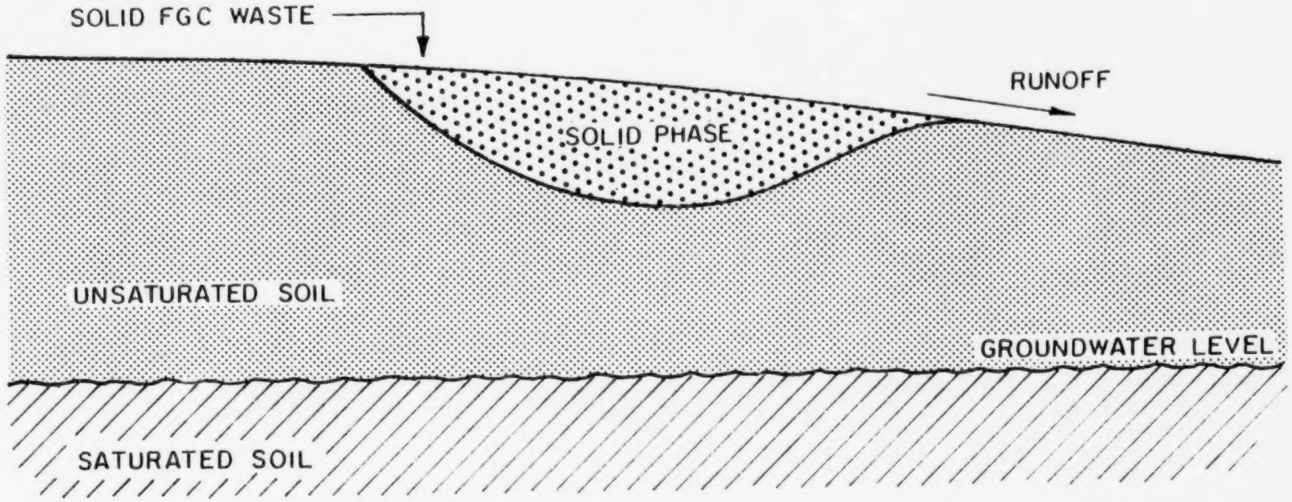
Similar to a wet disposal operation, assessment of a dry disposal (landfill) operation requires information about surrounding influents to, effluents from, and waste material present in the fill (Figure 4.2). Dry disposal, however, presents a different situation in the physical properties, mode of transport, and flow characteristics of materials (Table 4.2). The disposal site contents are expected to be non-fluid ash and FGD waste solids. The primary surface effluent is runoff waters (managed or unmanaged) from the site which is, as previously discussed, non-continuous and sporadic.

4.3.2 Sampling of the Contents of the Landfill

As with sampling of the pond contents, sampling of the landfill will be performed to determine the composition and properties, both physical and chemical, of the materials present in the site.

The approach for obtaining samples will involve the use of conventional drilling and coring techniques. Boreholes will be augered down to the desired sampling point using hollow stem augers, and a core will then be obtained by driving a thin-walled Shelby tube or split-spoon point through the hollow auger. (More details are presented in Appendix A, "Hydrogeologic and Geotechnical Procedures Manual.")

Samples which are not sufficiently cohesive to allow recovery in a thin-wall or split-spoon sampler (e.g., sand, fly ash, certain muds) may be obtained in a disturbed state by dry augering. Samples which are too hard to recover using thin-wall or split-spoon techniques (e.g., some stabilized FGC wastes) will be sampled using rotary rock-coring bits. Since samples for both physical and chemical properties will be taken using these methodologies, appropriate precleaning (Section 5) of all


SOLID FGC WASTE
RUNOFF
SOLID PHASE
UNSATURATED SOIL
GROUNDWATER LEVEL
SATURATED SOIL

Source: Arthur D. Little, Inc.

FIGURE 4.2 DRY DISPOSAL (LANDFILLING) INFLUENTS AND SURFACE EFFLUENTS

TABLE 4.2

DRY DISPOSAL – TYPICAL WASTES AND RELATED STREAMS[1]

Name	Physical Characteristics	Usual Mode of Transport	Flow Characteristics
Influents:			
Solid Waste	thick sludge or moist solid	conveyor belt or truck	discontinuous
Effluents (Surface)[2]:			
Runoff (liquid)	low suspended solids	surface flow (unmanaged or managed using pipe or ditch)	sporadic
Fill Content:			
Solid FGC Waste	moist solids	N/A	N/A

N/A = Not Applicable.

1. For illustration purposes only.
2. Underground effluents (e.g., infiltration occurring via continuous permeation are not normally included) since they are not directly able to be sampled.

Source: Arthur D. Little, Inc.

sampling equipment and other related materials will be required so as to minimize chemical contamination.

For an average site, an arbitrary range of 18 to 30 samples within the site is anticipated. (See Appendix A, "Hydrogeologic Geotechnical Procedures Manual.") These would be generally comprised of about six portions from differing depths from each of three to five borehole locations. Deviations from this average number of samples will be made depending upon the nature of the site. A dry landfill, comprised almost entirely of a treated waste material placed mechanically in a relatively ordered fashion, may require fewer samples for characterization. Decisions and recommendations as to the number of samples to be taken and analyzed for any particular site will be made during preparation of a specific site test plan after review of all site observations and data. The samples will be taken in conjunction with and at intervals described for the standard penetration tests discussed under pond sampling.

The location and number of the test borings will be site-specific; however, a maximum of three to five borings is most probable. The borings will extend to the bottom of the waste pile, and, in selected locations, will extend through the waste into the underlying soil liner and/or natural soil horizon.

4.3.3 Sampling of Landfill Influents

Generally, a portion of material which is representative of the waste being disposed of during each sampling period (i.e., 24 hours) will be obtained. For stabilized materials which require a curing period (generally 28 days) during which major changes in chemical and physical properties occur, samples will be obtained after disposal and/or after these wastes have been allowed to cure such that the sample obtained will represent waste properties that will be close to those obtained at equilibrium. The sample will be obtained as close as possible to the ultimate point of disposal. If the conveyance discharge point cannot be reached, then the next most acceptable sampling point may be the stockpile formed by the discharge. Sampling location will vary with disposal practice, and will be selected on a site-specific basis. In some cases, and with prior approval of the Project Director (or his designee), samples of wastes which have been aged or emplaced for some time may be taken.

Four samples representing the production during a work day (up to 24 hours) will be obtained over equal time increments (i.e., 2-3 hour intervals). These samples should be representative of production and should contain approximately two kilograms of dry solids. Samples of stabilized wastes will be taken so that they conform to the time criteria (age desired) where possible. Each sample may consist of a number of individual pieces or portions of stabilized waste. In addition, the process operation data (such as filter operating parameters) will be obtained in order to take an appropriate amount of sample for subsequent compositing in the laboratory. Compositing to yield a sample which is representative of the day's production will be done at the analysis laboratory.

If disposal is not occurring during the time of the visit, a decision will be made by consultation with the Project Director (or his designee) as to whether to obtain samples from the most recently disposed waste materials (i.e., materials already emplaced) or to postpone sample acquisition until the next visit.

Procedures for obtaining representative samples of solid materials are given in ASTM procedures (Ref. 4.6). The use of small sampling tools which may discriminate according to the size of pieces in the material in the sample will be avoided. A square shovel will be used for belt, worm screw, or truck conveyors. Ideally, a sample will be taken across the width of the conveyor discharge. This can be accomplished if the conveyor can be stopped momentarily. If such stoppage is impractical then the sampling team will make an effort to obtain material representative of same at the stockpile beneath the discharge.

The stockpile beneath or downstream from the conveyance will be sampled by augering to the bottom at least five points and recovering all material lifted by the flights. Alternatively, if a shovel is used to sample the pile, a sufficient amount of waste will be moved to obtain a sample representative of the cross section, i.e., not prejudiced to the outside and/or top of the pile. The portion taken will not have been excessively exposed to weathering (rain).

4.3.4 Sampling of Landfill Runoff

Runoff from a landfill may be managed (directed to culverts, ditches, etc.) or may be unmanaged with no direction of flow. In the case of managed runoff, the sampling techniques and flow measurements discussed under wet disposal (Section 4.2) are applicable and will be used. In some instances where runoff is not managed and flow measurement is needed, it may be necessary to create small ditches for sampling purposes.

In cases where ditches are not available or cannot be installed, a runoff plug collector will be used to obtain samples for chemical characterization. The use of plug collectors for obtaining background runoff samples (i.e., water flowing down the side of a hill prior to passing over the landfill) may also be required at some sites. When runoff is not managed, runoff flow rate will be estimated from rainfall, receptor area, and appropriate infiltration factors.

4.4 SOIL SAMPLING APPROACH

Samples of soils around and under landfills and ponds will be taken in conjunction with well placement and waste sampling, as described in Appendix A, "Hydrogeologic and Geotechnical Procedures Manual." The same techniques and approaches described for waste sampling in both ponds and landfills will be used for soils. At sites where coring through the waste/soil interface will be performed, samples of soils will be obtained and analyzed to determine the extent of contamination. Soil samples will also be taken around the site to obtain background samples for both physical and chemical analyses. In some cases artificial liners (e.g., poz-o-pac material) have been placed in building ponds. These materials which are not considered waste or natural soils around the site will also be sampled concurrent with the waste and soil sampling period. Samples of these liners will be characterized for both chemical and physical properties.

The techniques to be used in soil sampling will depend to a great extent on the location of the samples. For example, soil samples under a dry landfill will be obtained using the methods also used for obtaining samples of the waste. Similarly, samples of soil around the site will be obtained using these methods in conjunction with well placement. For samples of soils under a pond, the techniques for coring through the pond will be used to arrive at the sampling point. Techniques for obtaining solid samples (i.e., Shelby tube, etc.) will then be utilized.

As with waste sampling, soil sampling will be done in conjunction with standard penetration tests. For the control boring (Appendix A), samples will be obtained continuously [e.g., every 0.45 m (1.5 ft)]. For the remainder of the borings (wherever groundwater wells are placed and others as needed), samples will be taken at intervals [e.g., 1.5 m (5 ft)] to the groundwater table and at intervals [e.g., 0.76 m (2.5 ft)] from the groundwater level to the bottom of the well. The exact number and locations will be site-specific.

4.5 GROUNDWATER SAMPLING APPROACH

4.5.1 Introduction

The major objective for groundwater sampling will be the acquisition of portions of the groundwater existing at various points on the site. The choice of the optimal sampling procedure for a particular site and specific wells at a site will be made after a review of all available background hydrogeological and chemical data, including data from other existing groundwater wells, and will be based on the following parameters:

^ Well Casing Size. It is anticipated that most of the wells placed will be 5.1 cm (2 in.) in diameter.

- Recoverable Water Level. Consideration will be given to whether the water level is within suction lift [8.5 m (about 28 ft)] of a vacuum pump (termed a shallow well) or not (termed a deep well).
- Quantity of Standing Water in the Well.
- Recharge Rate of Water. The variation in recharge rate can span times of 0-6 hours ("fast"), 6-30 hours ("moderate"), and greater than 36 hours ("slow") and will affect the generally acceptable practice of removing the quantity of standing water in the well prior to sampling.
- Chemical Composition. Consideration will be given to whether special precautions are needed to minimize alteration of composition.

The categories of alternative sampling methodologies from which a method for obtaining groundwater samples from open monitoring (or observation) wells will be chosen include:

- Manual bailing (i.e., Kemmerer sampler);
- Vacuum pumping or aspiration (i.e., battery-operated peristaltic pump);
- Pressurized pneumatic pumping (i.e., bladder pump); and
- Gas (air) entrainment or lift.

Under each of these categories a number of alternative procedures can be employed. These procedures represent various equipment choices or configurations rather than differences in principle of operation. For a particular well the optimal configuration will be selected. In some situations existing wells may be sampled and existing sampling devices utilized if they are considered to satisfy the needs of the program.

A matrix of sampling approaches and methods for various well parameters is presented in Table 4.3. Additional discussion of groundwater sampling is given in Exhibit A.5-1.

4.5.2 Sampling Methods

TABLE 4.3

SAMPLING APPROACHES AND METHODS FOR VARIOUS WELL PARAMETERS

Water Level in Well	Proposed Sample Recovery and Prebailing Conditions		
	Slow Recharge One Time in More Than 30-36 Hours	Moderate Recharge One Time in 6-30 Hours	Fast Recharge One Time in 0-6 Hours
Distance between groundwater and grade level less than 7 m[1] Any amount of standing water in the well	Vacuum system (peristaltic pump) or pressurization No prebail	Vacuum system (peristaltic pump) or pressurization Prebail 1-3 times[2]	Vacuum system (peristaltic pump) or pressurization Prebail 3-5 times
Distance between groundwater and grade level greater than 7 m[1] Less than 2.25 m standing water	Manual bailing (Kemmerer) or pressurization No prebailing	Manual bailing (Kemmerer) Prebail 1-3 times[2]	Manual bailing (Kemmerer) or pneumatic pump Prebail 3-5 times
More than 2.25 m standing water	Manual bailing, pressurization, or pneumatic pump No prebailing	Manual bailing or pneumatic pump Prebail 1-3 times[2]	Manual bailing or pneumatic pump Prebail 3-5 times

1. Suction lift of 8.5 m minus 1.5 m required for water sample.
2. Lower number of prebailing will be used for the longer recharge rate.

Source: Arthur D. Little, Inc.

It is anticipated that for shallow well sampling a vacuum pumping system or pressurization of the well will be used. Both involve having a sample tube permanently installed in each well. The vacuum pump approach will be applicable to wells in which the requirements for water lift do not exceed 8.5 m (about 28 ft) but it suffers from possible sample alteration because of offgassing when a vacuum is applied. Forcing the sample out by pressurizing the well will eliminate that disadvantage but may cause well water to be forced back into the aquifer if its permeability is sufficiently great.

In practice, shallow wells for vacuum sampling would be equipped with a well cap through which is fed a small diameter tube [0.63 to 0.95 cm, (0.25 to 0.375 in.) inside diameter] made of Teflon or other inert material. The sampling tube will extend approximately 1 m (3.25 ft) away from the PVC well pipe but will still be retained within the outer protective casing. The end of the sampling tube will be equipped with an appropriate fitting to ensure both internal and external cleanliness. The sampling tube will extend below the water surface within the well in order to ensure adequate collection at minimal standing water. A chemically inert weight will be attached to the bottom of the sampling tube in order to hold it down. The well cap will be equipped with a small threaded plug which can be removed at the time of sampling to allow equilibration of the air column in the well with the atmosphere. In addition, a larger 2.5-cm (1-in.) threaded entry port will also be placed in the well cap in order to allow insertion of depth measurement devices without removing the cap.

Manual bailing techniques, well pressurization, and positive pressure pneumatic pumping systems will be used for deep well sampling. Manual bailing may require considerable time and effort if used exclusively for rapidly recharging wells.

The selected techniques will be compared at one or more well locations to determine if significant differences exist between the techniques.

4.5.3 Special Precautions

A key concern in groundwater sampling is to ensure minimal change in the composition of the analytes of interest during collection, preservation, and transport to the laboratory for subsequent analysis.

In addition to the mechanical aspects of sample acquisition the team will consider any need for special precautions in order to preclude changes in groundwater composition because of contact with the surface environment. In particular, if in-situ measurements of parameters such as dissolved oxygen, pH, and conductivity, which will be carried out either during site development or during subsequent sampling visits, indicate the likelihood of anaerobic conditions in the groundwater, it will be necessary to take precautions to exclude atmospheric oxygen from the well column during recharge and prior to acquisition of the analytical sample. Various means of excluding oxygen including flooding with inert gas (if well size and accessibility permit) or use of a small sealable bailing device will be considered.

It is generally accepted in groundwater sampling practice to remove three to five volumes of water from the well prior to actual sampling. This specification may need to be adjusted for each well depending on its recharge rate. For example, if a well recharges only once in 36 hours, only one volume of water can be removed prior to acquisition of the analytical sample within the estimated 36- to 40-hour period that a sampling team will be on the site. In contrast, for a well with a fast recharge rate, it will be possible to remove five volumes of water prior to acquisition of the analytical sample.

At least 1.5 liters of water will be required for chemical analysis purposes, and it is highly desirable that at least two times this quantity be recoverable from any well in order to permit rinsing of sample lines, containers, etc. One and a half liters corresponds to 75 cm (29.5 in.) of well depth for a 5.1-cm (2-in.) well. To obtain twice the desired sample quantity, a recoverable column of water of at least 150 cm (approximately 60 in.) in the well will be desirable.

In situations where only a minimum of standing water is available within a well, the 1.5-liter minimum sample volume requirements may dictate that all of the recoverable water contained within the well may have to be utilized for the actual sample.

In all cases, groundwater samples will be filtered (see Section 4.10) immediately after withdrawal from the well and with minimal contact with air prior to any stabilization.

Manual bailing techniques will be more appropriate for use in conditions of minimum standing water and slow or moderate recharge rates. Manual bailing allows for immediate transport of all of the collected water to the surface. In contrast, pneumatic pressure pumping or pressurization of the well may require staged evacuation of the well if the volume of available water in the well is comparable to the volume of the sample transfer line. This may increase the time required for the sample collection and the possibility of sample quality degradation.

4.6 SURFACE WATERS SAMPLING APPROACH

Available data from the utility and data bases such as STORET will be utilized prior to designing surface water sampling plans. If required, definition of the quality and flow of surface waters (lakes, streams, ponds)* will be made based on analysis of samples obtained at locations where contamination is most likely to be observed (closest to or downgradient from the source) and comparing analysis of these samples to analysis of samples at "background" locations which would be unaffected by the presence of the site. Analysis of these samples will be similar to that for groundwater samples but may not be as comprehensive.

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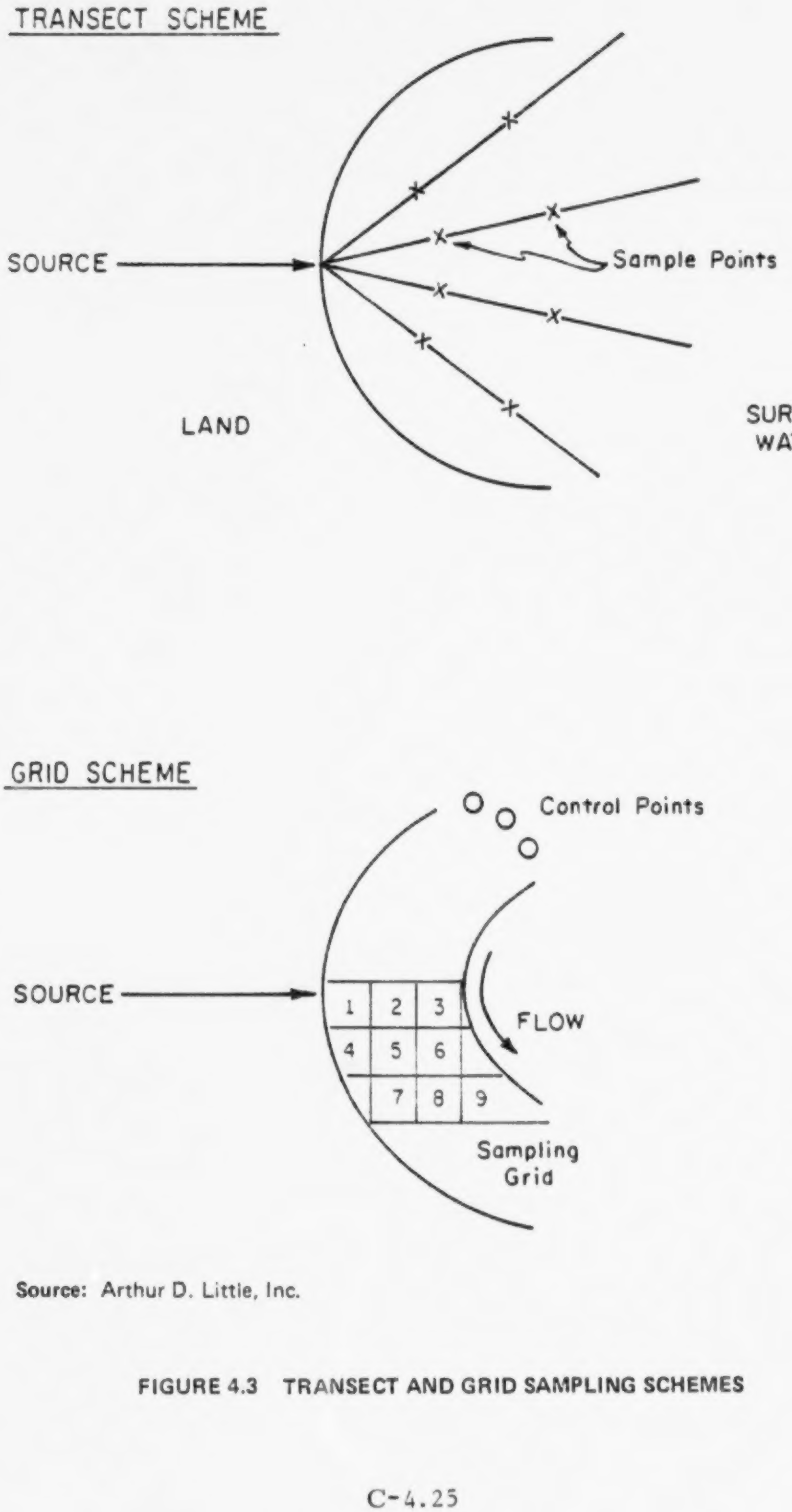
*Surface runoff is discussed in previous sections on influents and effluents to and from the disposal area.

The extent of surface water sampling is expected to be much less than that for groundwater and waste sampling. An average of 12 surface water samples per site is anticipated, although the number and location of sampling points will vary on a site-specific basis. Procedures given in Reference 4.7 will be used.

Definition of the location of sampling points will be made using such approaches as the schemes shown in Figure 4.3. Since the characteristics of particular sites can differ markedly sampling points will be chosen when site specific factors are known. Sampling points will be in locations varying in both width and depth directions. The choice of sampling points and supporting data will be made so that the following criteria will be met:

1. Representative samples of control waters, including the receiving water body upstream of the discharge of interest, will be obtained.
2. Representative samples of the non-point discharge to the receiving water body as close as possible in time to sampling the water body will be obtained.
3. Representative samples of the receiving water body downstream of the waste site will be obtained.
4. In large water bodies where contaminant dilution may limit detection, samples will be obtained as close as possible to the point of contact between groundwater and surface water.
5. Flow measurements of the direct discharge (overflow) and surface water body will be made (if appropriate).

Sampling locations will be chosen based upon estimates of the extent of mixing of the water body at the chosen locations in order to evaluate representativeness of the sample. The extent of uniformity due to mixing at various distances from the site will be initially estimated using the flow of the water body, its physical characteristics (depth/width), and a review of various water quality parameters (pH, dissolved oxygen, conductivity, temperature, and flow) under various surface body flow conditions. Based on these data in three dimensions (vertical,


TRANSECT SCHEME
SOURCE
Sample Points
LAND
SURFACE WATERS
GRID SCHEME
Control Points
SOURCE
1
2
3
4
5
6
7
8
9
FLOW
Sampling Grid

Source: Arthur D. Little, Inc.

FIGURE 4.3 TRANSECT AND GRID SAMPLING SCHEMES

horizontal, and longitudinal), a determination of the location of sampling points and the number of samples to be composited to yield a representative sample will be made.

Representative samples of the relevant discharges into the water body will be taken at the discharge point or near the intake of the discharge point. Several samples will be taken and composited. The extent of compositing will be determined based upon the quality of the effluent and whether it is expected to change significantly over the sampling period as determined by indicator parameters. This sampling procedure will be repeated several times during the year to permit assessment of variability during the various seasons. Data on the surface body flow, influent flow, and other meteorological data required will be obtained or calculated from plant and available surveys.

In order to more accurately measure the incremental impact of discharges on the surface water body quality, the samples of effluent and those from the water body will be taken within a short period of time (hours) to preclude variations caused by "pulses" of influents.

In cases where the water body is too large to be accurately sampled in the manner described above, sampling using a transect scheme would allow determination of local contamination of the surface water. Mapping the area with data obtained for the water quality parameter given above would allow initial estimates of the homogeneity of the water body near the discharge points.

Flow measurement will be made using velocity methods, level measurement methods, or other techniques as previously discussed.

Sampling methodology equipment such as a Kemmerer or Van Dorn bottle will be used because of their advantages in point sampling.

Sample volume, containers, and preservation will be similar to those used for groundwater sampling. The sample may be filtered in the field.

4.7 FIELD MEASUREMENTS

A variety of field measurements for both physical and chemical properties will be made at each site.

Standard penetration tests, vane shear strength tests, nuclear depth-density determinations, and field permeability tests will be performed on-site as described in Appendix A, "Hydrogeologic and Geotechnical Procedures Manual."

Measurement of the groundwater level in piezometers and wells will be made prior to prebailing or sampling. In addition, measurements will be made to determine and confirm recovery (recharge) of the piezometer and/or well. A battery-operated ohmmeter connected to a cable (which is marked at known increments) or an electrical cable connected to a measuring tape will be used. The tape or cable is weighted at the end with a plastic-coated weight. Detailed procedures are given in Exhibit A.7-1.

Measurement of conductivity, temperature, and pH will also be made where possible in sites in the well prior to withdrawing a well sample and on the withdrawn sample in the field. Obvious chemical changes in the sample during sampling or upon exposure to air (bubbling, precipitation, or rapid conductivity or pH changes) will be noted. Similar measurements will be made for other liquid or slurry samples (surface waters, waste streams) immediately after sample collection. Portable field meters (i.e., YSI Model 33 SCT meter), which are calibrated as per manufacturers' instructions, will be used.

Dissolved oxygen measurements for in-situ well waters and samples will also be made (in particular sites). A portable field meter (such as the YSI Model S-7 DO meter), which is calibrated as per manufacturers' instructions, will be used.

4.8 SAMPLE CONTAINERS

Factors which will be taken into account when choosing containers for the various types of samples discussed are compatability with the sample (i.e., neither contributing nor removing species of interest), resistance to breakage, and appropriate volume. The containers must have adequate wall thickness to withstand handling during sample collection and transport to the laboratory. Containers with wide mouths are desirable to facilitate transfer of samples from samplers to sample containers. The containers must have tight screw-type, chemically inert lids (i.e., caps and liners of plastic for plastic bottles and Teflon cap liners for glass bottles).

For this program the following containers will be used for the indicated sample/analysis categories:

Sample/Analysis	Container
waters/metals and inorganics	polypropylene or polyethylene
waters/organics	brown screw-cap borosilicate or flint glass, Teflon cap liners
slurries	same as above for water samples for metals and organics
solids	wide-mouth canning (Ball or Mason) jars, Teflon film under jar lid

Regardless of which sample containers are selected, they must be thoroughly cleaned prior to use to remove any contaminants such as oils, greases, dirt, or mold release agents that may be present. The recommended cleaning operation is presented in Exhibit A.8-1 and discussed in Section 4.9.

4.9 EQUIPMENT AND CONTAINER CLEANING

As a major objective of the chemical sampling and analysis activities centers around the measurement of trace-level quantities of metals species as well as some organic materials, it is absolutely essential that the sampling equipment and sample containers which come into contact with the samples be free of any substances which might transfer to the sample material. The cleaning protocol given in Exhibit A.8-1 has been utilized at Arthur D. Little, Inc. to clean glass and plastic sample containers as well as metallic sampling equipment prior to use.

While the quantities of solvents and aqueous solutions to be used in each step are not specified, sufficient volumes should be used in order to thoroughly soak and/or rinse both internal and external surfaces.

All new thin-wall tubing and other metal sampling equipment will be thoroughly degreased with acetone prior to carrying out the cleaning protocol. This degreasing operation should not be necessary once the equipment has been put in use.

To minimize inadvertent contamination of samples by stabilizers used in PVC manufacture, internal surfaces of the PVC well pipe will be cleaned, where possible, by washing with dilute nitric or hydrochloric acid solution and then thoroughly flushing with tap water prior to use.

Sample containers will be cleaned using a hot detergent wash and thorough tap water rinse followed by a nitric acid rinse. They will then be rinsed with tap water and distilled water in succession and finally with high-purity (MilliQ^{R}) water. For those containers which will be used to obtain samples for organic analysis the final rinse will be made with acetone. Final drying of the containers will be done in air. (See Exhibit A.8-1.)

4.10 FILTERING AND PRESERVATION OF SAMPLES

All groundwater, surface waters, slurry samples, and other liquid samples (as from ponds) will be filtered in the field with minimal exposure to air. Equipment for filtration will be composed of a reversible battery-operated peristaltic pump which forces the liquid to be filtered through flexible tubing into a back-flushing plate filter with a 0.45-micron filter (i.e., Leonard Mold and Die Works, Denver, CO.) preceeded by a coarse cellulose ester prefilter.

Preservation of various samples collected at the disposal site will be required to minimize loss of analytes during the storage and transport period prior to sample analysis at the laboratory. Solid samples which have no readily separable liquid will not be preserved. Slurry samples which are separable by filtration will be separated in the field (as above) and the liquid fraction preserved according to the analyte of interest (see below). The solid fraction will not be preserved. All other liquid samples will be filtered in the field and preserved in the following manner. The filtered sample will be split into two fractions: one fraction (for metals analyses) will be acidified to pH <2 with a fixed volume of concentrated nitric acid (e.g. 5 mL per liter of sample); the second fraction will be shipped in ice and maintained at 4°C in the laboratory until analyses are performed (for anions and other analytes). For samples and analytes which cannot be preserved by cooling or acidification either field analysis or special preservation techniques (e.g., mercury addition for trace sulfite) will be used.

4.11 FIELD DOCUMENTATION

Documentation during field activities will consist of the assignment of unique identifiers to each sample that is collected in the field, the recording and transmittal of all relevant ancillary observations, and the initiation of chain-of-custody procedures for each sample that is collected. A discussion of each of these activities is presented below.

4.11.1 Labels

Labels will be used to identify the origin and purpose of any material that is collected. Information contained on the label will be sufficient to uniquely describe the contents of the container so that misidentification of collected material is minimized. As a minimum, the label will contain the following information:

- Name or initials of the person(s) collecting the sample;
- Time of collection (month, day, year, and time);
- Place of collection; and
- A unique sample code.

An example of the proposed label is presented in Figure 4.4.

FIGURE 4.4

EXAMPLE OF SAMPLE CONTAINER LABEL

Arthur D. Little, Inc.
Acorn Park
Cambridge, Mass. 02140
617-864-5770

Collectors:
Date:
Sample №F 00248

Contractor: ADL TRW OTHER

Site Descriptor: 01 02 03 04 05 06 07 08 09 10 20 30 40

Type of Sample: GW SW RO WA SO OTHER

Location Index: 01 02 03 04 05 06 07 08 09 10 20 30 40
TP A B C D OTHER

Analysis Index: M + AN OR OTHER BLK DUP SPK

Comments:

Each subcontractor will be supplied with a quantity of these pre-printed labels.

4.11.2 Field Notebooks

Two types of field notebooks will be used during the performance of this contract. One will be used to record all pertinent field observations, and the second will be used to produce packing lists for samples returned to the laboratory.

The Observation Notebook will be used to record at least the following information:

- Purpose of sampling;
- Location of sampling site and its address;
- Name of field contact;
- Type of sample collected;
- Numbers and volumes of samples taken;
- Description of sampling site and conditions;
- Date and time of collection;
- References such as maps or photographs taken of all sampling sites;
- Field measurements made; and
- Signature of sampler making entry.

The information recorded should be sufficient so that others may reconstruct the sampling situation without having to refer to the collector's memory.

Because of the complexity of this program, it is suggested that a different Observation Notebook be maintained for each disposal site. In this way it will be possible to accumulate all data about that site over the sampling period in a single location.

The Packing Log will be a separate notebook that contains alternating bound and tear-out pages. As samples are being packaged for shipment, all sample label codes, along with the unique pre-printed label number, will be entered onto a permanent page that is backed by a piece of carbon paper. The tear-out page will serve as the packing list. This task will be performed by the designated crew chief. The same type of Packing Log should be used by all personnel who take and ship samples. Arthur D. Little, Inc. will acquire a sufficient quantity of log books for all concerned and distribute them as needed.

4.11.3 Chain-of-Custody Procedures

Chain-of-custody procedures will be initiated in the field. They will consist of documentation of all personnel who have handled the samples and sealing of sample bottles and shipping containers to detect any unauthorized opening of same. Detailed procedures are given in Exhibit A.11-1.

4.12 SHIPMENT OF SAMPLES

Shelby tubes will be sealed on each end with microcrystalline non-shrinking wax and capped and taped in preparation for transport. Each sample will be carefully logged with the job number, boring number, depth, and sequential sample number. In addition to Shelby tubes on samples scheduled for chemical analysis, two jar samples will be obtained for each standard penetration test. One jar sample will be sent to Bowser-Morner and the other sample will be sent to either TRW or Arthur D. Little, Inc., depending on the job responsibility.

Shelby tube and SPT jar samples will be boxed and crated for shipment. Samples for physical testing will be hand-carried by the Bowser-Morner site engineer on either the drilling equipment or through commercial airlines. The utmost care will be taken during packaging and shipment to ensure proper sample preservation.

Liquid and slurry samples for chemical analysis will be shipped from the test site to the analysis laboratory by the fastest possible commercial means (generally Air Freight or Courier).

Each sample container will be securely packaged to withstand the rough handling that is expected to be encountered. Each bottle will be individually cushioned with packing material such as bubble wrap, vermiculite, or styrofoam chips and placed in a shipping crate containing comparable padding. For those samples not requiring refrigeration, a heavy-walled corrugated cardboard, wood, polyethylene, or fiberglass container can be used. If samples are to be shipped in wet ice (see Section 4.10), the ice and samples should be within a plastic bag inside an ice chest. The plastic bag will be sealed to minimize water leakage out of the ice chest. The shipping crate will be securely sealed using nails, fiberglass-reinforced tape, or locks to minimize the chance that it will open during transport. The shipping crate will then be labeled to indicate point of destination and any appropriate handling precautions that should be taken (i.e., This Side Up, Fragile, Contains Glass, etc.). As possible, duplicate labels will be used to emphasize special handling precautions.

4.13 TERMINATION OF THE SAMPLING/ANALYSIS PROGRAM

Upon termination of sampling activities in this program, all non-permanent (mobile) sampling devices which are the property of EPA will be removed from all sites unless requested otherwise by the EPA Project Officer. Wells placed at the site will be turned over to the utility (if they so request) or sealed. If sealing is requested, the top of the well will be cut to ground level, and a sealer (bentonite pellets or cement) will be placed in the well to a minimum of 1.5 m (5 ft) above the uppermost opening of the screen. The remainder will be filled with soil. A similar sealing procedure will be used for any borehole drilled during the program for sampling purposes and which does not subsequently have a monitoring well installed in it.

5.0 PREPARATION OF SAMPLES FOR ANALYSIS

A variety of sample preparation procedures are required before chemical analysis by the various analytical techniques can be performed on samples taken from the field. These sample preparation procedures include compositing of samples, taking representative aliquots from the composites, drying of samples, separation of solid and liquid phases, digestion, and where appropriate extraction of samples.

Sample preparation prior to performance of physical tests is an integral part of the physical testing. However, this preparation is generally more test-specific than that performed for chemical testing and thus is described as part of the physical test procedures given in Section 6.

5.1 ALIQUOTING AND COMPOSITING OF SOLUTIONS, SLURRIES, AND SOLIDS FOR CHEMICAL ANALYSIS

Individual solution, slurry, and solid samples may need to be composited prior to performing chemical analysis. Aliquots of these composites or of individual samples will then be taken for analysis. Table 5.1 summarizes these procedures and a brief description of each procedure follows. Further details are provided in References 5.1, 5.2, and 5.3.

5.1.1 Solutions

Representative portions of solution samples will be obtained by pouring the individual sub-samples into a container, shaking or stirring to ensure that the samples are well mixed, withdrawing a sample volume slightly larger than that required from the vessel using a dry, clean container prerinsed with the sample of interest.

TABLE 5.1

SUMMARY OF ALIQUOTING/COMPOSITING PROCEDURES

Physical Form of Sample	Examples	Aliquoting Method	Compositing Method
Solutions (no suspended solids)	Pond liquor	Shake; pour aliquot	Combine aliquots in container; shake
Slurries (fluid suspensions)	Ash slurry	Continuously mix sample mechanically; use dipper to take three portions	Combine aliquots in container; mix
Solids (non-fluid wet[1] or dry)	Unstabilized FGD Stabilized FGD Ash	Dry to constant weight[2]; grind, if necessary, to reduce particle size using agate or alumina equipment; riffle through steel or aluminum riffler	Combine aliquots; cone-blend three times; roll-blend; cut and quarter

1. In cases where drying of sample may not be performed, the wet solids will be aliquoted using a small angled trier or split-tube sample; and the aliquots will be cue-blended three times, roll-blended, and cut and quartered.
2. Stabilized wastes will be freeze-dried; all others oven-dried. (See Section 5.2.)

Source: Arthur D. Little, Inc. and References 5.1 through 5.4.

5.1.2 Slurries

In this program, "slurries" will refer to any mixture of solids and solution in which the solids can be dispersed by mixing or agitation to yield a uniform suspension with fluid properties. Such suspensions can be handled as if they were a "solution."

If the solid's properties (density, size, etc.) are such that the solids tend to settle out extremely rapidly, the mixture may be more easily handled by allowing the phases to separate and handling them separately as solution and wet solids. (See Section 5.4.) The relative proportions of solution and wet solids resulting from separation would be used in deciding on the amounts of each phase required to give a representative sample. However, where practicable, direct sampling of the slurry is preferable to the separation method since it will afford a sample which is representative of the solid's composition.

In order to obtain an analytical aliquot from a slurry sample which is representative of the field sample it will be necessary to stir or mix the sample well both prior to and during the sampling operation. The ASTM procedure (Ref. 5.1) in which samples for analysis are taken by three successive transfers will be used.

The field sample will be stirred using a non-metallic mechanical agitator or impeller. Vortex formation and consequent air entrainment during stirring will be minimized. The analytical sample will be obtained by quickly dipping three portions approximately equivalent to one-third of the desired sample size, and combining these. Dipping will be done with a precleaned non-metallic dipper of appropriate size. Use of tube thieves or other devices which impede the mixing while the analytical sample is being taken and thus allow segregation during sampling will not be used.

The analytical sample so obtained will approximate the desired sample size and will be used intact for analysis.

5.1.3 Solids

Free-flowing non-cohesive solids can be blended and sampled using many of the conventional approaches which are applied to ores, industrial chemicals, etc. On the other hand, wet cohesive solids are much more difficult to blend to yield a material of homogeneous composition from which an analytical sample can be taken. Because of this difficulty in blending, especially where freedom from contamination by trace metals from blending equipment must be assured, all wet cohesive solids will be sub-sampled in the shipping containers by thieving; and a number of these sub-samples will be taken to constitute the analytical sample.

For free-flowing or dry hard materials, the entire field sample (one or multiple containers) will be transferred onto a precleaned sheet of plastic (polyethylene or polypropylene), and quickly examined for apparent homogeneity. The portion to be held in reserve will be immediately transferred to a precleaned container. Samples intended for analysis using an extraction procedure which includes an independent size-reduction technique (such as the EPA "Structural Integrity Test") will be removed at this point. The remainder of the field sample will be subdivided using a sequence of coning three times, roll-blending, and coning and quartering. Samples for determining the moisture content of the field sample will be taken for thieving after the third coning. Sub-sampling and rejection will continue until the sample is reduced to approximately two kilograms. If necessary, the sample may be ground using precleaned agate or alumina equipment to reduce any large-size particles. The sample will then be riffled three times through a laboratory riffler (steel or aluminum), and riffled sub-samples of approximately 7 ounces (200 grams) each will be retained in precleaned containers. Multiple sub-samples may be combined where appropriate.

Wet cohesive solids will be aliquoted using the following protocol. The field sample will be thief-sampled using a small angled trier or split-tube sampler. The sampling pattern will be such that the analytical samples are representative of the field-sample container geometry, and samples of the entire depth of the container will be obtained. Separate analytical sub-samples will be obtained by combining individual thief samples taken separately from within each of the geometric areas of the container. References 5.2, 5.3, and 5.4 give further details.

5.2 DRYING OF SAMPLES

Prior to analysis and/or compositing, solid samples will be dried to constant weight. Samples which require drying prior to chemical analysis include waste samples (after separation, if possible, from the liquid phase), stabilized FGD materials, and soil samples (after separation, if possible, of pore water). Drying of these samples prior to compositing will be performed to make the compositing process easier. Various drying conditions will be used for the different samples. Unstabilized FGC waste samples will be dried at 60°C for units at least 24 hours and until constant weight is achieved (ASTM D2216-63T, Note 2). Higher drying temperatures may lead to oxidation of calcium sulfite salts and dehydration of various salts. (See Reference 5.5 and Exhibit B.2.1.) Lower drying temperatures may require a longer period of time for drying.

Stabilized FGD materials will be freeze-dried. The use of higher temperatures may lead to further pozzolanic reactions and thus yield erroneous values of alkalinity and other parameters. Soil samples will be dried at 110°C to constant weight (ASTM D2216-63). Air drying to constant weight at a constant humidity at room temperature may be necessary for certain humic solids (ASTM D421-58).

Dried samples will be checked for chemical modifications, such as loss of trace elements during drying, by methods such as spiking with known amounts of trace elements prior to drying and analysis of undried samples for comparison. Samples of FGC wastes which will be subjected to an extraction procedure will not be dried.

5.3 SEPARATION OF SOLID AND LIQUID PHASES

Separation of solid and liquid phases prior to chemical analysis will be necessary for wet solid samples to obtain samples of both phases, and for liquid samples to remove any suspended solids present. Several separation methods are available including centrifugation, vacuum filtration, and pressure filtration. Of these, pressure filtration appears to be the most generally applicable to the range of sample types and conditions anticipated in this program. With suitable equipment, applied pressures may be varied over a considerable range. Equipment such as that specified in the Federal Register (Ref. 5.6) will be used, where applicable.

In cases where the routine methods above do not yield a volume of liquid sufficient for analysis, high pressure will be applied to the sample to attempt to force additional liquid out. The apparatus used will have a cylindrical body constructed of stainless steel and a Teflon-padded plunger. (See Exhibit B.3-1 for details.) A 20-ton press will be used to apply pressure on the plunger. For each test the sample will be supported on 325-mesh stainless screen (precleaned with acetone to remove grease) to provide initial filtering of the expressed liquid. The expressed liquor will then be filtered through a 0.45 um filter to remove fine particles prior to analysis.

Filtration of liquids will be carried out using pressure filtration equipment specified by EPA in References 5.6 and 5.7 (i.e., Teflon-coated units such as Millipore TY30-142HW). Filters which will be used in conjunction with the apparatus will be low in trace elements and/or organics depending on the analysis. (See Reference 5.7.)

5.4 DIGESTION AND PREPARATION PROCEDURES

Various digestion and preparation procedures will be used to prepare both solid and liquid samples for analysis. For analytes other than metal ion species, these procedures are individually described in the analytical method given in Section 7. For metal ions analysis, digestion procedures will vary depending on sample type and metals to be analyzed and will range from acid digestion to fusion. A summary of these procedures for liquid samples and solid samples is given in Tables 5.2 and 5.3, respectively. Additional details are given in Exhibit B.4-1 and the appropriate references.

Liquid samples which have been preserved by addition of nitric acid (HNO_3) for analysis of metals by ICAP, plasma emission, and graphite furnace AA (see Table 5.2) will not be further digested. If addition of HNO_3 to filtered samples or dilution of samples results in production of a precipitate, further treatments in the lab to afford dissolution will be required. These will be treated on a case-by-case basis. Samples, if needed, will be diluted using water acidified with HNO_3 to minimize the possibility of precipitation and loss of metals which might otherwise result from the change of pH upon dilution. Specific digestion procedures will be used for As, Se, and Hg because of the nature of the analytical method used subsequent to digestion. Predigestion and preparation prior to some analytical methods (i.e., ICAP) are not needed due to the powerful decomposing properties of the plasma and/or flame.

The first set of solid FGC waste and soil samples from each site will be digested using procedures which afford complete dissolution of the sample at some point during the digestion process (i.e., by addition of HF to dissolve silicates) rather than partial dissolution, which may leave an unattacked residue (Table 5.3) possibly containing some trace elements. After initial screening of these total digestion methods, further tests will be performed to determine if less comprehensive digestion procedures (i.e., those which do not dissolve the sample completely) are as effective as the total digestion and are more cost-effective.

TABLE 5.2

DIGESTION PROCEDURES FOR LIQUID SAMPLES[1] METALS ANALYSIS

Analyte	Analysis Method	Digestion[3]	References
Various Metals[2]	ICAP	None	Ref. 5.8
Various Metals[4]	Flame AA, Graphite Furnace AA and dc Plasma Emission	None or HNO_3	Exhibit B.4-1
As, Se	Hydride Evolution	HNO_3/H_2O_2	Ref. 5.9
As, Se[4]	Graphite Furnace AA	HNO_3/H_2O_2	Ref. 5.9
B, Si	dc Plasma Emission	None	—
Hg	Cold Vapor AA	HNO_3/H_2SO_4 in glass reflux to sulfuric fumes, dichromate addition[6]	Ref. 5.10
Hg[4]	Graphite Furnace	None [5]	Ref. 5.11

1. Filtered and preserved (nitric acid) groundwater, FGC liquors, extracts, surface waters, and similar samples.
2. As given in Table 7.5 and Section 7.
3. Prior to analysis method described in appropriate reference.
4. Alternative method.
5. Dichromate addition prior to injection.
6. Oxidation step with $HClO_4$ is omitted.

Source: Arthur D. Little, Inc.

TABLE 5.3

DIGESTION PROCEDURES FOR FGC SOLID AND SOIL SAMPLES METALS ANALYSIS

Analyte	Sample Description	Analysis Method	Digestion/Preparation	Comments	References
Various Metals[4]	FGC waste and soils (with low organic content)	ICAP	HF/$HClO_4$/HNO_3 to fumes, make up in HCl	1, 2	Exhibit B.4-1
Various Metals[5]	As above	Flame AA	As above	1, 2, 3	–
Various Metals[5]	As above	dc Plasma Emission	As above	1, 2	–
Various Metals	FGC waste and soils (with high organic content)	ICAP	$HClO_4$/HNO_3 reflux to $HClO_4$ fumes HNO_3/HF to $HClO_4$ fumes, make up in HCl	1, 2	Exhibit B.4-1
Various Metals[5]	As above	Flame AA	As above	1, 2, 3	–
Various Metals[5]	As above	DC Plasma Emission	As above	1, 2	–
Hg	FGC waste and soils (with low organic content)	Cold Vapor AA	HNO_3/H_2SO_4 in glass reflux apparatus, to sulfuric fumes, addition of HF in Teflon to dissolve residue, make up in HNO_3, dichromate addition	2	Exhibit B.4-1 and Refs. 5.10, 5.12
Hg	FGC waste and soils (with high organic content)	Cold Vapor AA	H_2SO_4/HNO_3 in glass reflux apparatus, $HClO_4$ to sulfuric fumes, add HF to dissolve residue, make up in HNO_3, dichromate addition	2	Refs. 5.10, 5.12
Hg[5]	FGC waste and soils	Cold Vapor AA	Aqua Regia, permanganate	6	Refs. 5.11, 5.13
Hg[5]	FGC waste and soils	Graphite Furnace AA	HNO_3/dichromate addition	6	Refs. 5.11, 5.13
As, Se	FGC waste and soils (low organic content)	Hydride Evolution AA	Same as for Hg (low organic content) except make up in HCl		Exhibit B.4-1 and Ref. 5.12

TABLE 5.3 (Continued)

Analyte	Sample Description	Analysis Method	Digestion/Preparation	Comments	References
As, Se	FGC waste and soils (high organic content)	Hydride Evolution AA	Same as for Hg (high organic content) except make up in HCl	6	Ref. 5.12
As, Se^5	FGC waste and soils	Graphite Furnace AA	HNO_3/H_2O_2, nickel nitrate addition	6	Ref. 5.14
Sb + other metals	FGC waste and soils	Graphite Furnace AA	HNO_3	6	Ref. 5.15
B, Si	FGC waste and soils	dc Plasma Emission	Na_2CO_3 fusion, make up in HCl		Ref. 5.16
Si^5	FGC waste and soils	dc Plasma Emission	CaO_2 or $LiBO_2$ fusion, make up in HCl		Ref. 5.16
B	FGC waste and soils	dc Plasma Emission	CaO fusion, make up in HCl		Ref. 5.16

Comments:

1. HF leads to loss of volatile fluorides which thus cannot be analyzed in this digest.
2. This digestion provides total dissolution of silicate-type materials.
3. The presence of $HClO_4$ cannot be tolerated in graphite furnace AA.
4. The Various Metals are listed in Table 7.5 and Section 7.
5. Alternative Procedure.
6. Partial dissolution of sample if silicates present.

Source: Arthur D. Little, Inc.

For some types of solids (i.e., calcium sulfate, FGD materials, etc.) some reprecipitation of dissolved species following a complete digestion may occur when the samples are diluted prior to analysis. Attempts will be made to avoid formation of precipitates where loss of trace elements can occur because of encapsulation by and/or adsorption on the precipitates formed; however, such losses may be unavoidable in some situations (precipitation of calcium sulfate after fusion). In all tests, quality control procedures including spiking and recovery measurements and standard reference materials will be used to determine and confirm the applicability and reliability of the methods.

For analysis by ICAP, FGC waste solids and most soils will be digested in a mixture of $HF/HClO_4/HNO_3$ acid. This total dissolution procedure will lead to loss of volatile metal fluorides (e.g., Si), and those species cannot be analyzed subsequent to this digestion. For highly organic material a $HNO_3/HClO_4$ digestion prior to addition of HF will be used. These digestions for ICAP analysis, and possibly other analyses by Flame AA dc plasma emission will be carried out by Barringer-Magenta, Ltd. (Toronto, Canada). A portion of this digest will be sent to Arthur D. Little, Inc. or TRW (depending on who is performing the sampling and analysis at the particular site) for analysis of certain metals by Flame AA dc plasma emission as needed. (See Section 7.)

Prior to analysis of mercury by the cold vapor-AA technique, solids will be totally digested in HNO_3/H_2SO_4 in a reflux condenser and HF added to dissolve any residue. Perchloric acid will also be used in this digestion for solids with a high organic content. (Ref. 5.12.) An alternative procedure for mercury sample digestion which does not effect total dissolution of silicate-type materials will also be used and compared to the total digestion procedure. This procedure involves digestion using Aqua Regia followed by stabilization with permanganate (Ref. 5.13) or nitric acid with dichromate addition. These digestates would be used for analysis of mercury by cold vapor AA and graphite furnace AA, respectively.

Prior to analysis of arsenic and selenium by hydride evolution, solid samples will be digested using the same procedure for total dissolution used for Hg analysis of low or high organic-content samples except that HCl will be used for makeup (after HF addition to dissolve any residue). A digestion method which does not totally dissolve the sample will be compared for cost-effectiveness. This method utilizes a HNO_3, H_2O_2 digestion for analysis of these elements by graphite furnace AA.

In all cases the inability to analyze perchloric acid solution using the graphite furnace AA technique and the possibility of etching of glass or quartz apparatus or instrument components by HF solutions will be considered, in addition to other quality control considerations such as recovery and losses during the digestion process.

Prior to analysis of boron and silicon, solid samples will be fused with sodium carbonate (Ref. 5.16) and the melt dissolved in dilute HCl. Precipitation of calcium sulfate salts may be unavoidable at this point for some FGD samples. Redissolution may be effected by dilution at the expense of sensitivity. The solution could be analyzed by dc plasma emission. If total dissolution is not effected using this approach, alternative fusion (e.g., CaO and $LiBO_2$ for Si) will be used.

6.0 PHYSICAL LABORATORY TESTING PROCEDURES

6.1 INTRODUCTION

Physical characteristics of FGC wastes must be known to properly evaluate the potential for environmental impact via leaching; further, knowledge of physical properties is of value in determining the disposal economics of a particular waste-generating methodology and deposit. An important aspect in determining the physical engineering characteristics of a waste deposit is the selection of field or laboratory testing conditions. Field testing provides quantitative information on the type and extent of the deposit and also provides relative density, strength, permeability, and compressibility data. Laboratory tests performed on disturbed and undisturbed samples are conducted under more controlled conditions and provide more precise determinations of some engineering properties.

The following field and laboratory tests are planned for the FGC waste testing program:

Field Tests	**Laboratory Tests**
Vane Shear Strength	Natural Moisture Content
Standard Penetration	Grain Size
Field Permeability	Specific Gravity
Nuclear Density	Compaction (Proctor)
	Compressive Strength
	Permeability/Consolidation

It is not intended that all of the above tests will be performed at every site or on every sample. The type and quantity of physical tests performed at a given site generally will depend on the type of waste disposal (wet or dry). Test requirements (type and quantity) will be site-specific and will be described in the site-specific test plans. Typical laboratory and field tests to be performed at a landfill disposal site and a wet-pond disposal site are given in Tables 6.1 and 6.2, respectively.

ASTM standards will be followed during the physical

TABLE 6.1

DRY LANDFILL MODEL SITE:
TYPICAL PHYSICAL TESTING QUANTITIES

Quantity/Site[1]	Item
Laboratory Testing (Number of Tests)	
5	Extended Permeability/Consolidation Tests (Solids Content vs. Permeability)
6	Grain-Size Determinations
6	Specific Gravity Determinations
20	Moisture-Content Determinations
1	Consolidated-Undrained Triaxial Compression Test with Pore Pressure Measurements (TCTWPPM) (3-point envelope)
6	Standard Proctor Tests
Drilling, Field Testing, and Sampling[2]	
33 meters (100 feet)	Drilling length
20	Standard Penetration Test or Vane Shear Tests
10	Shelby Tube Samples or Stationary Piston Samples (3-inch, thin-wall)
25	Nuclear Density Tests

1. The exact quantity of borings and tests will be site-specific.
2. In borings where considerable sampling and testing is involved, auxiliary borings will be installed at 1.5-meter (5-foot) offsets to obtain additional samples.

Source: Bowser-Morner Testing Laboratories, Inc.

TABLE 6.2

WET POND MODEL SITE: TYPICAL PHYSICAL TESTING QUANTITIES

Quantity/Site[1]	
Laboratory Testing (Number of Tests)	
6	Field Permeability Tests
15	Grain-Size Analyses
15	Specific Gravity Determinations
40	Moisture Content Determinations
Drilling and Field Testing	
33 m (100 ft)	Drilling length
40	Standard Penetration Tests or Vane Shear Tests

1. To be modified at time of compilation of Site Development Plan.

Source: Bowser-Morner Testing Laboratories, Inc.

laboratory testing program. Bowser-Morner standards will be used for tests not covered by ASTM. The tests and applicable standards will be used as shown below. Detailed procedures are given in References 6.1 through 6.7.

Physical Laboratory Tests	**Specifications**	**References**
Natural Moisture Content	ASTM D 2216-71	6.1
Index Tests	ASTM D 854-58	6.2
	ASTM D 424-59	6.3
Compaction Tests	ASTM D 698-78	6.4
Strength Tests	ASTM D 2166-66	6.5
	ASTM D 2250-70	6.6
	ASTM D 2434-68	6.7
	Bowser-Morner	Exhibit C.2-1
Permeability/Consolidation Tests	ASTM D 2434-68 Bowser-Morner	6.7 Exhibit C.2-2

Unstabilized and stabilized FGC materials and pozzolanic materials will generally be tested similarly in physical testing procedures. It is anticipated that most stabilized waste samples taken will have been "placed" in the field under normal operating conditions and will have been naturally cured so that minimal changes in properties will occur with time after sampling. In some cases, uncured stabilized samples may be taken for comparison purposes.

6.2 PHYSICAL LABORATORY TESTING PROCEDURES

6.2.1 Natural Moisture Content Determinations

The moisture content is defined as the weight of water divided by the weight of solids and will be determined for all recovered samples in accordance with ASTM D 2216-71 (Ref. 6.1). Note 2 of the ASTM D 2216-71 specification will apply for oven-drying FGC waste materials. A drying temperature of 60°C is recommended because sulfate-rich FGD sludges break down to anhydrite at higher temperatures, thus, the 60°C temperature will be maintained for all moisture content and related determinations.

6.2.2 Index Tests

Grain size analyses, Atterberg limits tests, and specific-gravity determinations will be performed to determine index properties of the waste materials. ASTM standards will apply for all index testing. The specific gravity is defined as the ratio of the weight in air of a given volume of material to the weight in air of an equal volume of distilled water at a temperature of 4°C. The specific gravity is used in weight-volume calculations. ASTM D 854-58 (Ref. 6.2) standards will be used for specific-gravity determinations.

Grain-size analyses include sieve and hydrometer analyses for determining the percentage (by weight) of particles with a given effective diameter in a sample of solid waste particles.

Atterberg liquid and plastic limits are defined as the moisture contents corresponding to arbitrarily defined liquid and plastic consistencies. Since most of the wastes involved in this program are anticipated to be non-plastic, Atterberg limits probably will not be relevant. If cohesive wastes are encountered, Atterberg limits will apply. Actual engineering properties of cohesive soils have been correlated to Atterberg limits, and these tests are important soil index tests for this reason. The ASTM D 424-59 (Ref. 6.3) standard will apply for the liquid and plastic limits.

These tests (index and specific gravity) will be performed on the waste materials to determine whether correlations with measured engineering properties exist.

6.2.3 Compaction Tests

The standard Proctor laboratory compaction test will be used as a standard to evaluate the field placement techniques at the dry and landfill disposal sites. The percentage of compaction being obtained in the field as compared to the standard Proctor maximum dry unit weight can be obtained by determining field densities of the waste materials. This information will be valuable in determining whether additional compactive effort or better moisture content control is effective in increasing field density. If field and laboratory testing indicate that the engineering properties can be improved by increasing the waste density, then the Proctor data will indicate to what extent the density can be increased. ASTM specification D 698-78 (Ref. 6.4) will apply for all standard Proctor compaction tests.

6.2.4 Strength Tests

Knowledge of the shear strength of the wastes is necessary in determining stability of fill and retaining structures. The majority of the wastes are anticipated to be cohesionless materials. In most instances, consolidated-undrained triaxial compression tests with pore pressure measurements will be performed to determine effective strength parameters of the cohesionless wastes amd soils. Wastes that have been treated with lime and fly ash to form pozzolanic bonds could also be subjected to unconfined (uniaxial) compression or unconsolidated-undrained triaxial compression testing. Since ASTM procedures do not cover consolidated-undrained triaxial compression tests, the tests will be performed according to Bowser-Morner specifications as described in Exhibit C.2-1. Unconfined compression and unconsolidated-undrained triaxial compression tests of cohesive wastes will be performed according to ASTM specifications D 2166-66 (Ref. 6.5) and ASTM D 2250-70 (Ref. 6.6), respectively.

6.2.5 Permeability Tests

Permeability is an engineering property which indicates the ease with which a fluid flows through a particulate substance. Since the coefficient of permeability of a waste material will influence the rate of flow through the material and to groundwater resources, the permeability testing program is considered the most important physical laboratory test for this project. Also, the relation of coefficient of permeability to waste solids content is important in evaluating whether or not permeability of dry fills can be decreased by increasing density through increasing compaction effort or by better controlling field moisture content. Extended laboratory permeability tests will be performed on undisturbed samples so that coefficients of permeability can be related to solids content.

Solids content for samples subjected to the extended permeability/consolidation tests will be increased by consolidation in a triaxial compression chamber. Compressibility characteristics of the waste also will be determined from the extended permeability tests by measuring the volume change-time relationships during consolidation. The initial permeability testing procedure will follow general guidelines of ASTM D 2434-68 (Ref. 6.7). Adaptation to the triaxial compression chamber will be performed according to Bowser-Morner specifications as described in Exhibit C.2-2.

7.0 CHEMICAL LABORATORY TESTS

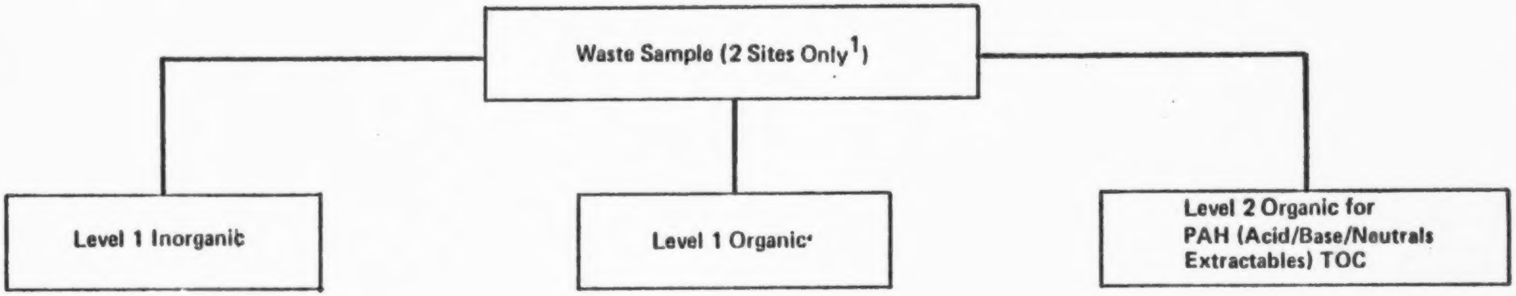
7.1 INTRODUCTION

Chemical analysis of the FGC waste samples obtained at each of the sites will be performed in two stages. The first stage will involve screening of selected samples at two sites using the methodology shown in Figure 7.1. The results of these screening tests and other chemical data which will be gathered from existing studies will be used to further define the extent of more complete analyses of various samples. Analysis schemes for ash, slurry, wet FGC waste, dry FGC waste, stabilized FGC waste, groundwater, or surface water and soil samples are presented in Figures 7.2 through 7.7. The particular analysis scheme for samples from a site will be tailored to the samples involved. The distribution of effort between analysis of more samples versus a more complete analysis of fewer samples will be made using factors such as waste properties, numbers of wells, and previous available data. If the option of taking more samples is used, the number of analyses performed on a particular sample will be limited, based on a priority ranking given in Tables 7.1 through 7.3.

In general, multi-element analysis techniques (ICAP, IC) and pH and conductivity analyses will be performed (where applicable) on most samples. The number of other types of analyses will generally be lower than that of the techniques mentioned above. The ranking with regard to choice of the type of sample to be analyzed (Table 7.3) emphasizes the liquid rather than solid phases because of the mobility requirement for environmental contamination which liquids provide.

The extent of chemical characterization of some samples may be reduced for particular species if these species are found to be below predetermined concentration limits (e.g., analysis detection limits) during analysis of initial samples.

For wastes which do not yield a sufficient volume of liquid phase for analysis by laboratory separation techniques (Section


Waste Sample (2 Sites Only[1])
Level 1 Inorganic
Level 1 Organic
Level 2 Organic for PAH (Acid/Base/Neutrals Extractables) TOC

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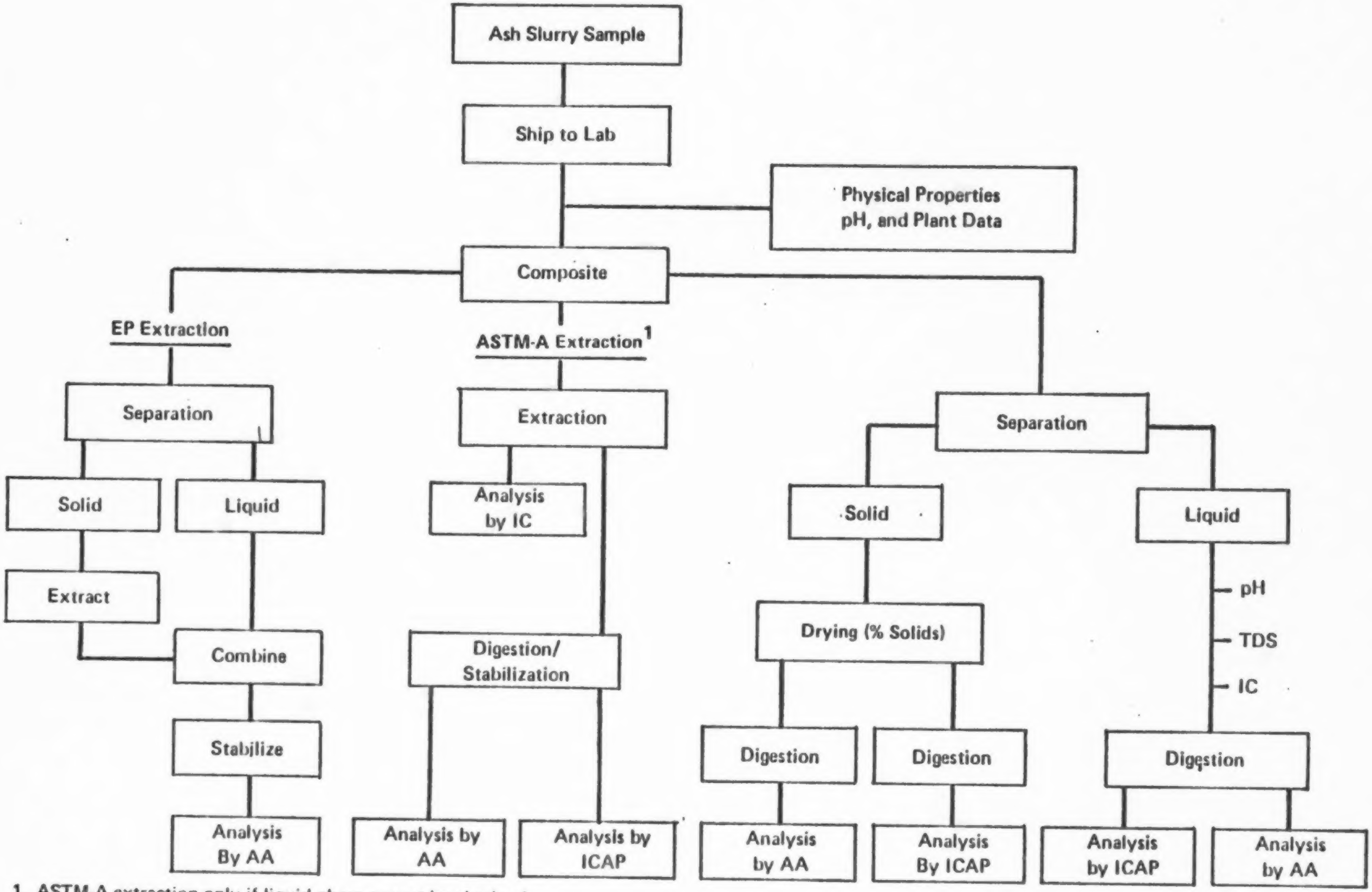
[1] One FGD-containing waste, and one ash-only waste.

Source: Arthur D. Little, Inc.

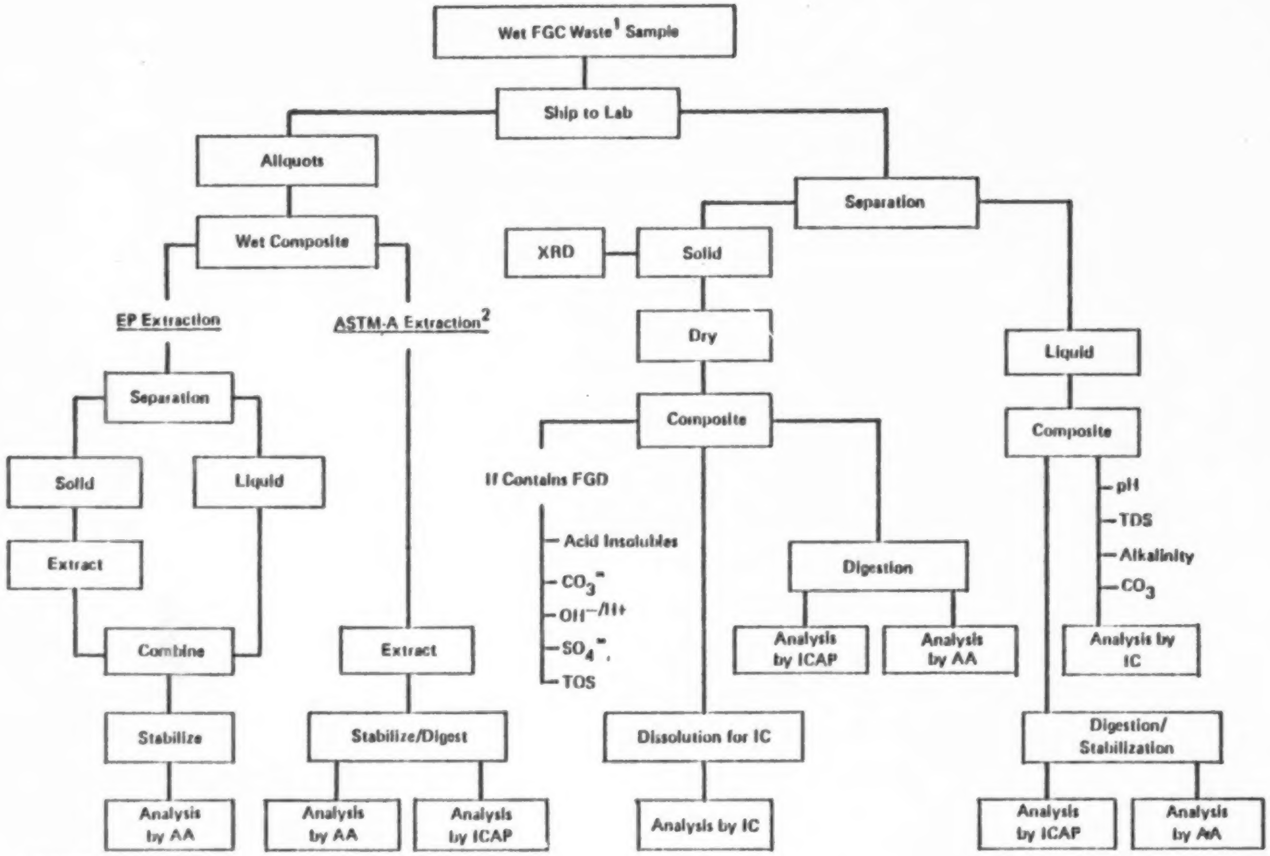
FIGURE 7.1 INITIAL SCREENING ANALYSES OF WASTE SAMPLES


Ash Slurry Sample
Ship to Lab
Physical Properties pH, and Plant Data
Composite
EP Extraction
ASTM-A Extraction[1]
Separation
Solid
Liquid
Extract
Combine
Stabilize
Analysis By AA
Extraction
Analysis by IC
Digestion/ Stabilization
Analysis by AA
Analysis by ICAP
Separation
Solid
Drying (% Solids)
Digestion
Digestion
Analysis by AA
Analysis By ICAP
Liquid
pH
TDS
IC
Digestion
Analysis by ICAP
Analysis by AA

1. ASTM-A extraction only if liquid phase cannot be obtained.

Source: Arthur D. Little, Inc.

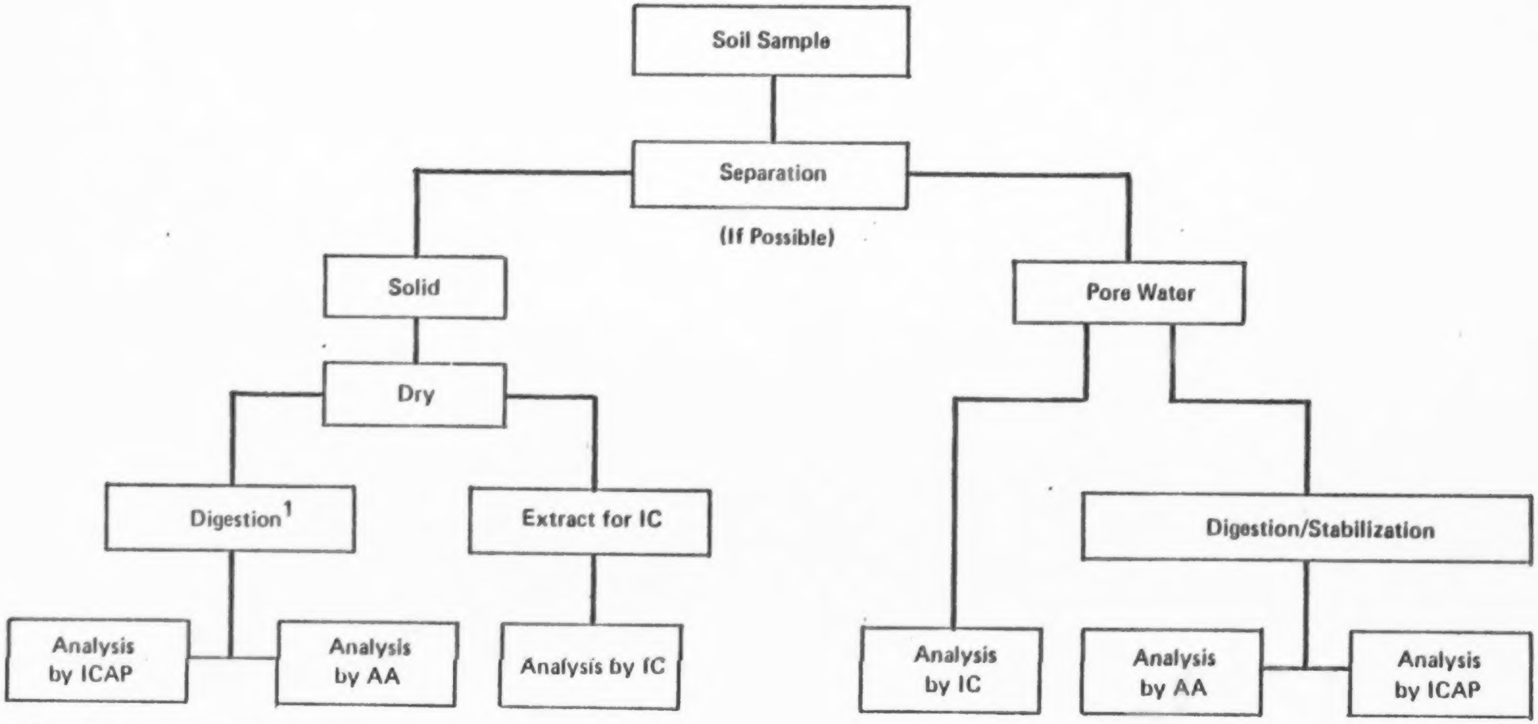
FIGURE 7.2 ASH SLURRY SAMPLE ANALYSIS SCHEME


Wet FGC Waste[1] Sample
Ship to Lab
Aliquots
Wet Composite
EP Extraction
Separation
Solid
Liquid
Extract
Combine
Stabilize
Analysis by AA
ASTM-A Extraction[2]
Extract
Stabilize/Digest
Analysis by AA
Analysis by ICAP
Separation
XRD
Solid
Dry
Composite
If Contains FGD
Acid Insolubles
CO3=
OH−/H+
SO4=
TOS
Dissolution for IC
Analysis by IC
Digestion
Analysis by ICAP
Analysis by AA
Liquid
Composite
pH
TDS
Alkalinity
CO3
Analysis by IC
Digestion/ Stabilization
Analysis by ICAP
Analysis by AA

1. FGC Waste = Ash + FGD.
2. ASTM A extraction only if liquid phase cannot be obtained.

Source: Arthur D. Little, Inc.

FIGURE 7.3 WET FGC WASTE SAMPLE ANALYSIS SCHEME

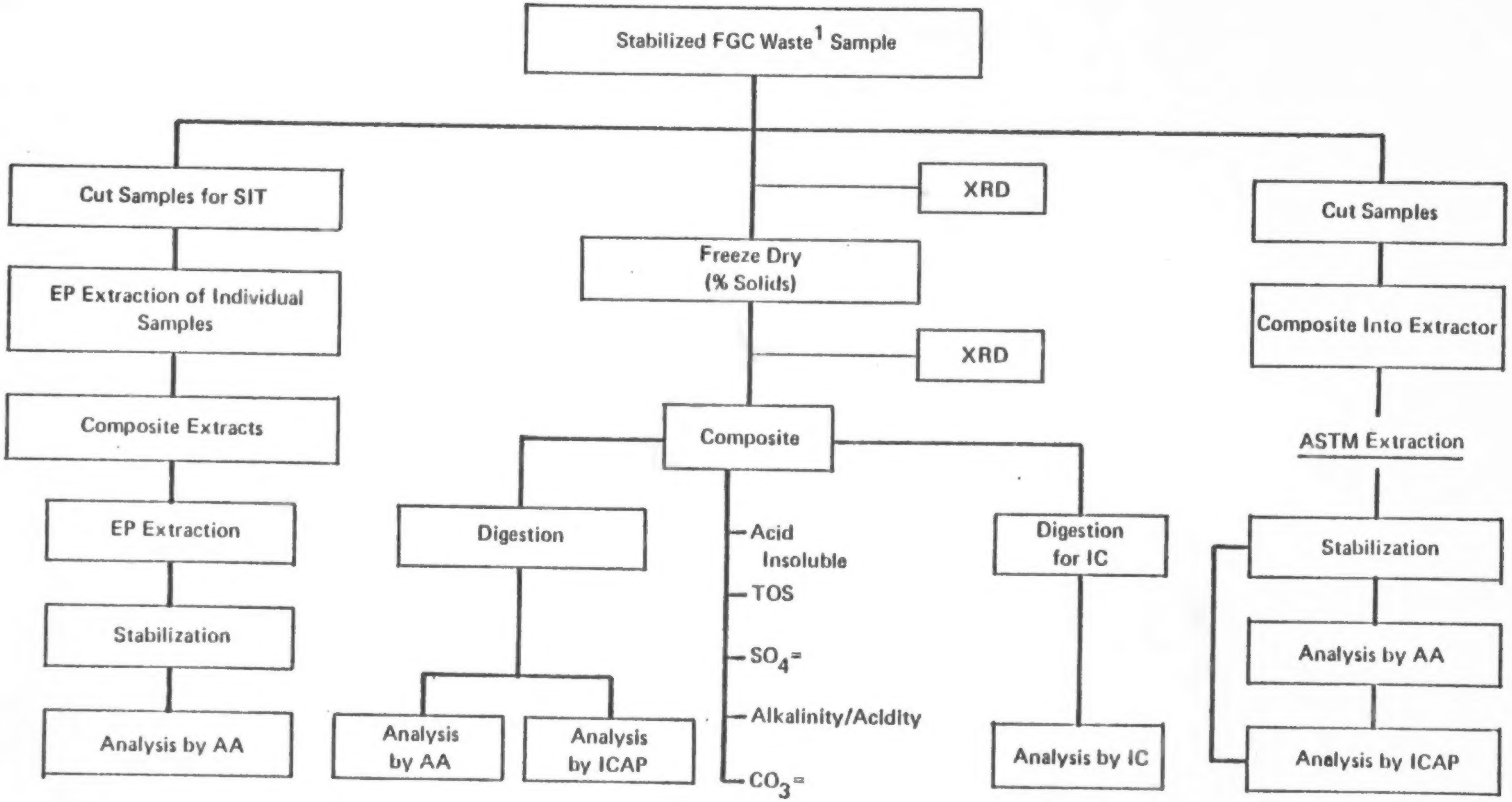

Soil Sample
Separation
(If Possible)
Solid
Pore Water
Dry
Digestion[1]
Extract for IC
Digestion/Stabilization
Analysis by ICAP
Analysis by AA
Analysis by IC
Analysis by IC
Analysis by AA
Analysis by ICAP

May Be Limited by Sample Size

FIGURE 7.4 SOIL SAMPLE ANALYSIS SCHEME

1. Extraction or total dissolution.

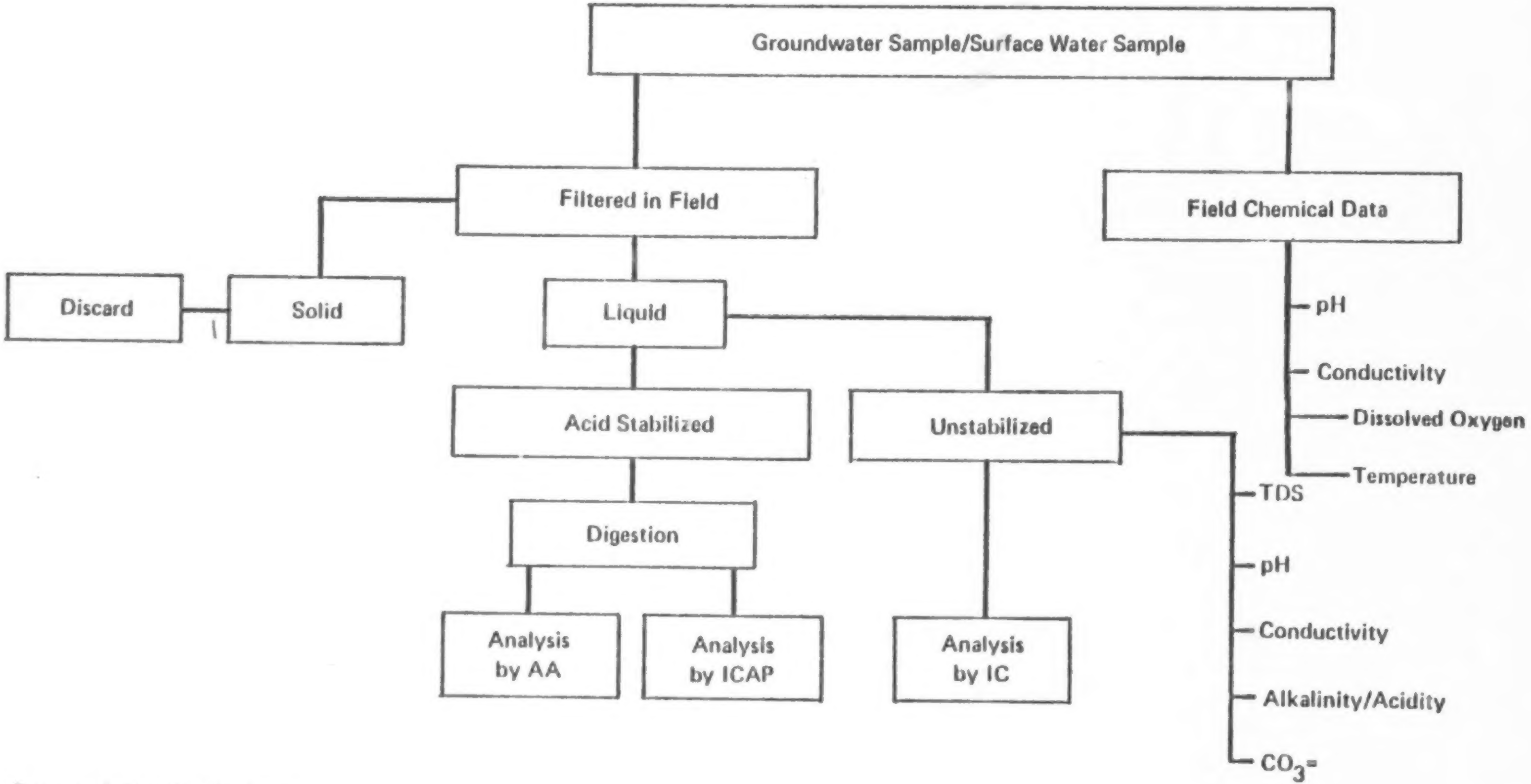
Source: Arthur D. Little, Inc.


Stabilized FGC Waste¹ Sample
Cut Samples for SIT
EP Extraction of Individual Samples
Composite Extracts
EP Extraction
Stabilization
Analysis by AA
XRD
Freeze Dry (% Solids)
XRD
Composite
Digestion
Analysis by AA
Analysis by ICAP
Acid Insoluble
TOS
SO4=
Alkalinity/Acidity
CO3=
Digestion for IC
Analysis by IC
Cut Samples
Composite Into Extractor
ASTM Extraction
Stabilization
Analysis by AA
Analysis by ICAP

1. FGC Waste = Ash + FGD.

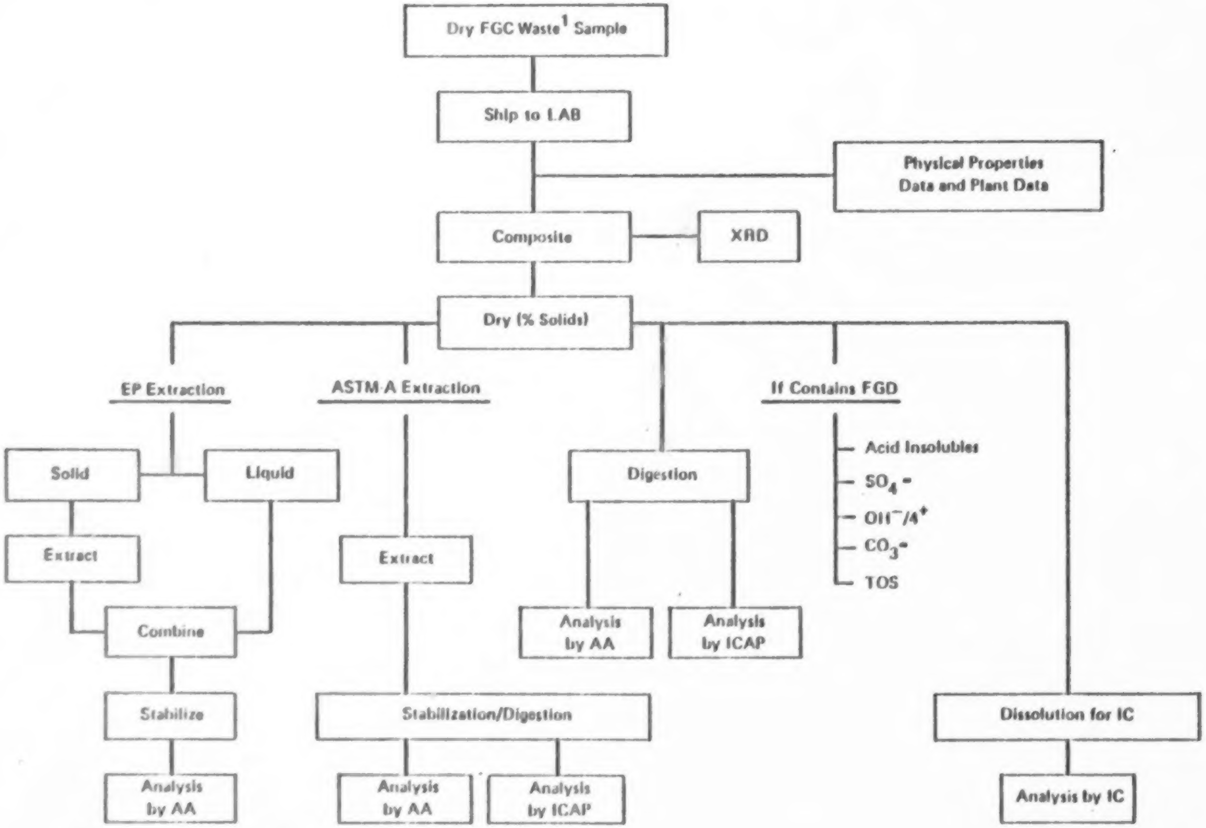
Source: Arthur D. Little, Inc.

FIGURE 7.5 STABILIZED FGC WASTE SAMPLE ANALYSIS SCHEME


Groundwater Sample/Surface Water Sample
Filtered in Field
Field Chemical Data
Discard
Solid
Liquid
pH
Conductivity
Dissolved Oxygen
Temperature
Acid Stabilized
Unstabilized
TDS
Digestion
pH
Conductivity
Alkalinity/Acidity
$CO_3^=$
Analysis by AA
Analysis by ICAP
Analysis by IC

Source: Arthur D. Little, Inc.

FIGURE 7.6 GROUNDWATER AND/OR SURFACE WATER SAMPLE ANALYSIS SCHEME


Dry FGC Waste[1] Sample
Ship to LAB
Physical Properties Data and Plant Data
Composite
XRD
Dry (% Solids)
EP Extraction
ASTM A Extraction
If Contains FGD
Solid
Liquid
Extract
Combine
Stabilize
Analysis by AA
Extract
Stabilization/Digestion
Analysis by AA
Analysis by ICAP
Digestion
Analysis by AA
Analysis by ICAP
Acid Insolubles
$SO_4^=$
$OH^-/4^+$
$CO_3^=$
TOS
Dissolution for IC
Analysis by IC

1. FGC Waste = Ash + FGD.

Source: Arthur D. Little, Inc.

FIGURE 7.7 DRY FGC WASTE SAMPLE ANALYSIS SCHEME

TABLE 7.1

PRIORITY RANKING OF CHEMICAL ANALYSES FOR LIQUIDS

Rank	Method	Analytes/Reason
1	Instrumental	pH, conductivity/low cost, good overview of sample
2	Inductively Coupled Argon Plasma – (ICAP) (24 metals)	Ba, Ag, Cr, Pb (primary drinking water)[1] Ca, Fe, Mn, Zn (secondary drinking water)[1] Ca, Na (good FGC tracers) Al, Be, Cd, Co, Cr, K, Mg, Mo, Ni, P, Sr, Th, Ti, V, Zr/low cost multi-element analysis for many species of interest (analyzed simultaneously with above species)
3	Ion Chromatography (IC)	F^-, NO_3^- (primary drinking water) Cl^-, $SO_4^{=}$ (secondary drinking water, good FGC traces) Br^-, $PO_4^{\equiv}$, NO_2^-/low-cost multi-species analysis for species of high interest (separated during analysis of other species)
4	Atomic Absorption – (AA)	Se, As, Cd, Hg (primary drinking water, good FGC traces) higher-cost individual analysis of very important species
5	Atomic Absorption – (AA)	Sb / high-cost individual analysis of metal not specified in proposed drinking water criteria
6	Atomic Emission – (AE)	Si, B / same as above.
7	Gravimetry	TDS, / high-cost individual analyses of parameters not of great importance
8	Wet Chemical	CO_3^{2-}, alkalinity, acidity / mass balance, high-cost individual analyses. Some idea of alkalinity and acidity is also obtained from pH values.
9	Spectrophotometry/IC	SO_3^{2-} (importance may be higher in sulfite-rich wastes) / high-cost, low probability of detection due to ease of oxidation. IC may be used to analyze for low levels of sulfite if appropriate preservation techniques appear consistent with the analysis method.

1. Reference 7.1

Source: Arthur D. Little, Inc.

TABLE 7.2

PRIORITY RANKING OF CHEMICAL ANALYSES FOR SOLIDS

Rank	Method[1]	Analytes/Reason
1	ICAP (24 metals)	(see liquids)
2	AA	Se, As, Cd, Hg / (see liquids)
3	Wet Chemical	Alkalinity, acidity/pH in secondary water standards
4	Wet Chemical	$SO_4^=$ / in secondary drinking water Interim Standards
5	Wet Chemical	Total Oxidizable Sulfur (TOS)[2], Acid Insolubles / characterization of waste
6	AA	Sb / lower-importance metal
7	AE	B / lower-importance species
8	AE	Si / mass-balance data
9	Wet Chemical	CO_3^{2-} / mass-balance data, waste characterization
10	X-Ray Diffraction – XRD	Confirmation or identification of bulk solid phases

1. See Table 7.1 for abbreviation meaning.
2. May be ranked same as 3 for sulfite-rich wastes.

Source: Arthur D. Little, Inc.

TABLE 7.3

RANKING OF SAMPLES WITH REGARD TO IMPORTANCE OF CHEMICAL ANALYSIS

WASTE CHARACTERIZATION:

Rank	Item/Sample	Reason
1	Liquids	Greatest environmental impact route and interest
2	Solids	Reservoir of pollutants, waste site characterization

OVERALL SAMPLES:

Rank	Sample	Reason
1	Groundwater	Determination of impact
2	Waste	Reservoir (liquid first, then solid) of potential impact
3	Non-Point Discharge (runoff)	Impact related
4	Surface Waters (lakes, streams)	Impact related (non-point discharge receptor)
5	Soils[1]	Attenuation and future impact related

1. May be ranked higher (3) for regions where groundwater contamination is expected to be less important or as yet undetectable.

Source: Arthur D. Little, Inc.

TABLE 7.4

SAMPLE SAMPLING AND ANALYSIS CHEMICAL MATRIX
(For a Typical Site for a Twelve-Month Monitoring Period)

Sample Type	Analysis Type[1] (No. of Samples)
Waste (previously disposed)	ICAP (18), IC + other (18), AA + other (6)
Waste (currently disposed)	ICAP (4), IC (4), + AA (4), EP (1), ASTM (1)
Groundwater	ICAP (90), IC (90), AA + other (30)
Soils	ICAP (30), IC (30), AA (selected number)
Surface Waters	ICAP (12), IC (12), AA + others (6)

1. A complete description of analytes is given in Sections 7.2 to 7.7. The abbreviations refer to the following Analyses: ICAP — Inductively Coupled Argon Plasma Emission, IC — ion chromatography, AA — atomic absorption, EP — EPA extraction procedure, ASTM — ASTM extraction method, others — other analytical techniques including atomic emission, gravimetric, wet chemical. See Tables 7.1 and 7.2.

Source: Arthur D. Little, Inc.

6), a water extraction (e.g., ASTM Method A, Ref. 7.2) will be carried out. Water was selected as the extraction fluid because it resembles more closely the properties of the natural leaching media which may occur at the dry disposal sites (e.g., rain water). The EPA Extraction Procedure will be applied to waste grab samples prior to the initiation of full-scale sampling and analysis.

An example matrix of samples and number of samples to be analyzed by various analysis methods for a given site are given in Table 7.4. A specific matrix will be generated for each site.

All of the analytical methods proposed in this section will be checked during a method qualification period to determine their applicability for the various samples in this program.

7.2 INDUCTIVELY COUPLED ARGON PLASMA (ICAP)

Multi-element analysis of a variety of samples will be performed using ICAP analysis. Although ICAP has not as yet been referenced by EPA as a standard analysis technique, EPA has recently proposed its use for analysis of trace elements in water and wastes (Ref. 7.3).

In this study the following types of samples will be analyzed by ICAP for the elements listed in Table 7.5:

- Filtered groundwater samples;
- Liquid phase of disposed FGC wastes obtained by various separation techniques;
- Liquid phase of soil samples obtained by pressure filtration;
- Digest samples of solid phases of FGC waste samples;
- Digest samples of soils;
- EP (Acetic acid) extract of FGC waste samples;
- ASTM-A (water extract) of FGC waste samples; and
- Filtered surface water samples.

ICAP analysis will be performed by Barringer-Magenta, Ltd. (Toronto, Canada), who operate a large-scale ICAP testing service laboratory.

TABLE 7.5

ICAP DETECTION COMPARED WITH SAMPLE CONCENTRATIONS AND OTHER CONCENTRATIONS OF INTEREST

No.	Element	ICAP Detection in Solution[1] (ppm)	Groundwater Quality Criteria[2] (ppm)	FGC Waste Liquors[3] (ppm)	ICAP Detection in Solids[4] (ppm)	FGC Waste Solids (ppm)	Comment: Likely to Need Supplemental Analysis
1	Ag	0.05	0.05	ppb	5	1-50	yes
2	Al	0.5		—	50	major comp.	no
3	B	0.05		ppb-ppm	5	10-1000	yes, lost in digestion
4	Ba	0.05	1.0	ppb-ppm	5	10-1000	no
5	Be	0.005		0.0005-0.05	0.5	1-50	possibly
6	Ca	0.5		100-3000	50	major comp.	no
7	Cd	<0.07	0.01	0.004-0.1	100	0.5-10	yes
8	Co	0.5		0.002-0.1	50	2-400	possibly, not major interest
9	Cr	<0.008	0.05	0.001-0.5	10	20-400	no, AA detection similar
10	Cu	0.05	1.0	0.002-0.4	5	4-1000	no, AA detection similar
11	Fe	<0.2	0.3	0.02-0.1	10	major comp.	no
12	K	10.0		0-200	1000	major comp.	possibly for solids
13	Mg	0.1		0-3000	10	major comp.	no
14	Mn	<0.01	0.05	<0.01-9.0	10	5-1000	no, AA detection similar
15	Mo	0.3		0.9-5	200	1-10	yes, if of sufficient interest
16	Na	20.0		10-30000	2000	major comp.	possibly for solids
17	Ni	0.5		0.03-0.9	50	3-500	yes
18	P	5.0		—	500	—	no, not major interest
19	Pb[5]	<0.05	0.05	0.002-0.5	200(2)	5-1000	no
20	Si	0.5		—	50	major comp.	yes, lost in digestion
21	Sr	0.01		—	1	5-10,000	no
22	Th	0.1		—	10	2-20	no, not major interest
23	Ti	0.05		—	5	major comp.	no
24	V	0.05		ppb-ppm	5	2-800	possibly
25	Zn	<0.02	5.0	0.01-27	5	2-1000	possibly
26	Zr	0.2		—	20	20-1500	no

1. Ten times detection limits quoted by vendor (Barringer-Magenta).
2. *Federal Register*, December 18, 1978.
3. "Assessment of Technology for Control of Waste and Water Pollution from Combustion Sources," Arthur D. Little, Inc., report to EPA, Volume III, Generation and Characterization of FGC Wastes, Contract No. 68-02-2654, August 1979. (Ref. 7.4)
4. 100 times solution detection limits for digestion of 1 g in 100 mL.
5. ICAP analysis includes AA analyses for these elements (AA detection limits are given in parenthesis).

Source: Arthur D. Little, Inc.

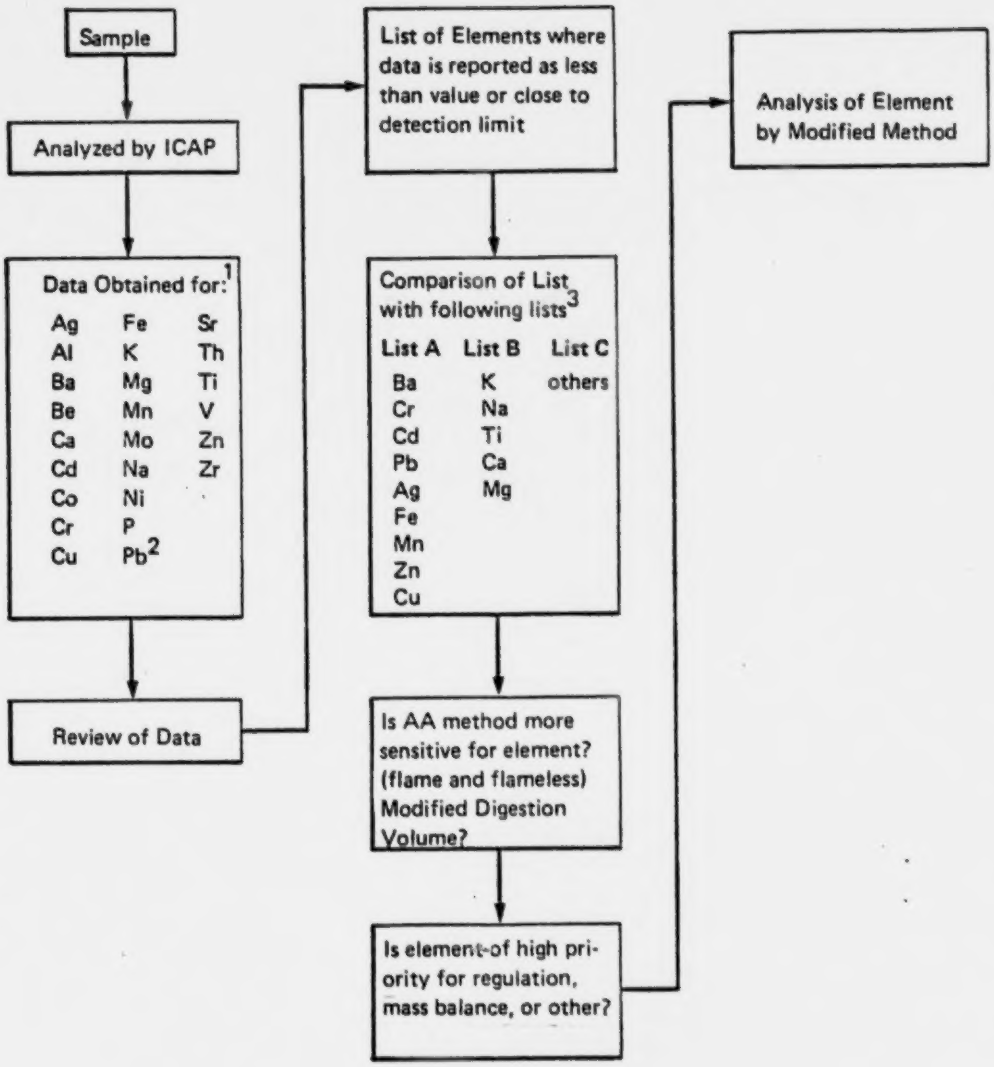
A comparison of the ICAP detection limits (defined as ten times detection limits reported by the ICAP laboratory to account for possible matrix problems) for 26 elements versus reported concentration ranges of these elements in some FGC liquors, FGC solids, and proposed groundwater quality criteria are also given in Table 7.5. Detectability in solids has been defined for the purpose of this table as 100 times that in solution because of the digestion step which produces a 100-fold dilution. ICAP detection limits for most elements are lower than the anticipated concentration ranges in the corresponding sample types. This fact demonstrates that ICAP is suitable for analysis of many elements at the desired range for many of the samples. However, this is not universally true. For this reason, and also because the relative cost of ICAP is significantly lower than individual analyses of elements by AA or other techniques, the following approach will be used. ICAP will be used as a screening method. Where the data obtained by ICAP analysis is close to or below the ICAP detection limit and the element is of sufficient importance (see Figure 7.8), the analysis will be repeated using atomic absorption spectroscopy or another appropriate technique. This approach is illustrated schematically in Figure 7.8.

A summary of the elements which, because of the anticipated concentration range in most samples, are considered likely to be analyzed only by the ICAP vendor and elements which for the same reasons are likely to require analysis by AA or other methods is given in Table 7.6.

On at least two waste samples the level 1 Inorganic Protocol which includes SSMS will be performed to provide data on elements not included in the above techniques.

7.3 METALS BY ATOMIC ABSORPTION (AA)

This section describes procedures which may be used to analyze trace metals in digests of FGC waste solids, interstitial liquors, and samples of surface water or groundwater. Atomic absorption methods are anticipated to be required for arsenic,



Sample
Analyzed by ICAP
Data Obtained for:[1]
Ag Fe Sr
Al K Th
Ba Mg Ti
Be Mn V
Ca Mo Zn
Cd Na Zr
Co Ni
Cr P
Cu Pb[2]
Review of Data
List of Elements where data is reported as less than value or close to detection limit
Comparison of List with following lists[3]
List A List B List C
Ba K others
Cr Na
Cd Ti
Pb Ca
Ag Mg
Fe
Mn
Zn
Cu
Is AA method more sensitive for element? (flame and flameless) Modified Digestion Volume?
Is element of high priority for regulation, mass balance, or other?
Analysis of Element by Modified Method

1. B and Si require a different digestion and thus will be analyzed separately.
2. Analysis by vendor using AA methods provided simultaneously.
3. List A — Proposed Groundwater Quality Criteria metals.
   List B — Important for mass balance.
   List C — Site specific (e.g., aquatic toxicity for Cu).

Source: Arthur D. Little, Inc.

FIGURE 7.8 DECISION PROCESS FOR USING ICAP AND/OR FLAME OR FLAMELESS AA

TABLE 7.6

POSSIBLE ELEMENTS DISTRIBUTION BY ANALYSIS

ICAP Vendor (Includes Pb by AA) Elements Likely to be Analyzed by ICAP	Element Likely to Need AA Back-up Method	Elements Possibly But Not Likely to be Analyzed by Back-up AA Method	Elements Anticipated to Require AA or Other Method
Al	Ag	Be	Cd
Ba	Ni	Co	B (plasma emission)
Ca	Cd	K	Si (plasma emission)
Cd		Mo	Hg
Cr		Na	Se volatile
Cu		V	As species
Fe		Zn	Sb
Mg			
Mn			
P			
Pb			
Sr			
Th			
Ti			
Zr			

Source: Arthur D. Little, Inc.

selenium, antimony, mercury, and other elements listed in Table 7.6.

Cadmium will need to be determined by AA because it is very likely to be found at levels which may be of concern but which are below ICAP detection limits. It is also likely that silver and nickel may be present at levels of concern which are also below ICAP detectability. A comparison of AA detection limits for these and other elements with Proposed Groundwater Quality Criteria (Ref. 7.1) and the range of levels which have been observed in FGC samples is shown in Table 7.7.

7.3.1 Arsenic (Hydride Evolution or Graphite Furnace)

The generally accepted high-sensitivity method for determining arsenic involves converting the arsenic to arsine (AsH_3) by first reducing all arsenic to As (III) with NaI and then converting it to AsH3 with $NaBH_4$. Immediately upon formation, the AsH_3 is sparged from the reaction solution by a stream of argon which sweeps it into the air-hydrogen flame of an atomic absorption spectrometer. A detailed procedure for this determination is included in Exhibit D.3-1.

Recent advances in AA technology have produced a graphite furnace procedure for measuring arsenic that appears to rival the hydride evolution method in sensitivity while offering definite advantages in analytical throughput. Nickel nitrate is added to the sample to produce a nickel arsenide which is sufficiently non-volatile to permit furnace measurement. The sample is placed in the graphite furnace which is electrically heated first at low temperature to dry and ash the sample, and then heated to 2900°C to atomize the sample for AA measurement. A detailed procedure for this EPA analysis method is given in Reference 7.4.

During method qualification, these two methods will be compared using various FGC and other samples.

7.3.2 Selenium (Hydride Evolution and Graphite Furnace)

TABLE 7.7

DATA FOR METALS THAT MAY REQUIRE ANALYSIS BY A METHOD OTHER THAN ICAP

(For Elements of Sufficient Importance)[1]

Element	AA Detection[2] in Solution (ppm)	Proposed Groundwater[8] Quality Criteria (ppm)	Concentrations in[9] FGC Liquors (ppm)	ICAP Detection[3] in Solids (ppm)	Concentrations in[9] FGC Solids (ppm)	Comment on Overall Detection
B[4]	0.02 (dc plasma)	–	ppb-ppm	2	10-1000	OK
As[4]	0.02 (hydride, furnace)	0.05	< 0.004-1.8	2	0.6-63	Borderline
Se[4]	0.01 (hydride, furnace)	0.01	< 0.001-2.7	1	0.2-19	Borderline
Hg[4]	0.01 (cold vapor)	0.002	< 0.001-0.07	1	0.001-6	Borderline
Sb[4]	(graphite furnace)					
Ag[5]	0.01 (graphite furnace)	0.05	ppb-ppm	1	1-50	Probably OK
Cr[6]	0.1 (flame)	0.05	< 0.001-0.5	10	3-250	Borderline
Cu[6]	0.04 (flame)	1	< 0.002-0.6	4	1-76	OK
Mn[6]	0.08 (flame)	0.05	< 0.01-90	8	11-120	Borderline
Fe[6]	0.05 (flame)	0.3	0.3-10	5	major comp.	OK
Zn[6]	0.06 (flame)	5	< 0.01-27	6	10-430	OK
Cd[6]	0.01 (furnace)	0.01	0.004-0.1	1	0.5-10	Borderline
Pb[6,7]	0.05 (flame)	0.05	0.002-0.5	5	5-1000	Borderline

1. See Tables 7.5 and 7.6 for background.
2. Ten times detection limit (Arthur D. Little data), includes a dc plasma method.
3. 100 x solution detection limit. Barringer-Magenta, Ltd. data.
4. Definitely requires AA.
5. Possibly requires AA.
6. Not likely.
7. AA performed by ICAP vendor.
8. *Federal Register*, Dec. 18, 1978.
9. Note 3, Table 7.5 (Ref. 7.4).

Source: Arthur D. Little, Inc.

The state of the art of trace selenium analyses is analogous to that of arsenic which was described above. A method involving the formation of gaseous H_2Se has been the generally accepted method. A graphite furnace procedure may supplant the hydride evolution technique. Procedures based on hydride evolution are given in Exhibit D.3-2. The EPA graphite furnace procedures are given in Reference 7.5.

7.3.3 Antimony (Graphite Furnace)

Antimony can be determined by AA with the graphite furnace using the EPA procedure given in Reference 7.6. The addition of a reagent to reduce antimony volatility is not necessary.

7.3.4 Mercury (Cold Vapor)

"Cold vapor" techniques for ultra-trace determinations of mercury have been used for many years. In one such technique a reaction vessel fitted with a sparger is connected to an optical cell placed in the measurement beam of an AA spectrometer with Tygon tubing. The exit port of the cell is connected back to the sparger inlet of the reaction vessel via a peristaltic pump to form a closed system. A sample of the solution to be analyzed is placed in the reaction vessel and the mercury is reduced to highly volatile elemental mercury by adding stannous chloride. The peristaltic pump circulates the mercury vapor from the vessel to the AA measurement cell. The details of this procedure are presented in Reference 7.7. A graphite furnace technique will be compared for cost-effectiveness and applicability (Ref. 7.8).

7.3.5 Other Metals By AA

Silver, nickel, and cadmium will also be analyzed by graphite furnace techniques analogous to the procedure for antimony. The EPA methods which will be used are given in References 7.9 through 7.11.

Further discussion of the relative applicability of the various hydride and graphite furnace methods for As, Se, Hg, and Sb is given in Exhibit D.3-3.

7.4 ION CHROMATOGRAPHY (IC)

Ion chromatography is a relatively new instrumental technique for measuring a number of commonly occurring anions in solution at sub-ppm levels. A small (generally 100 uL) sample of the solution to be measured is injected into an aqueous carrier stream containing a dilute sodium carbonate/bicarbonate mixture. The anions in the sample are carried through an anion exchange column where separation occurs. After the conductivity of the carbonate/bicarbonate in the carrier is "suppressed" by converting it into carbonic acid, the anions are quantified using an electrical conductivity detector.

In this program IC will be used to measure fluoride, chloride, nitrate, and sulfate in liquid samples.

In instances where fluoride or chloride is the only substance of interest, it may be more cost-effective to measure it using the fluoride or chloride ion-specific electrode. (See Section 7.5.10.)

Anions in the following types of samples will be measured during the program:

- Liquid phase of waste materials;
- Interstitial water in soils;
- Groundwater;
- Water extracts of soils and waste samples; and
- Surface water samples.

Detailed procedures on using an ion chromatograph (DIONEX Model 14) are given in Exhibit D.4-1. A comparison of IC detection limits and concentration of the listed anions in various samples of interest and proposed standards is given in Table 7.8 and illustrates the applicability of this technique for analysis of the various samples of interest in the program.

TABLE 7.8

COMPARISON OF IC DETECTION LIMITS WITH SOME RANGES OF INTEREST

(all values in ppm)

Species	Limit IC	Proposed Drinking Water Standards	Typical Concentrations in FGD Liquors	FGC Waste[1]
F-	0.05	1.4-2.4	0.7-70	1-20
NO_3^-	0.3	10*	–	2
Cl^-	0.07	250	470-43,000	1-10
$SO_4^=$	0.1	250	100-30,000	10-400

*as N, 44 ppm as NO_3^-.

1. Provided for comparison only. For 1-g sample dissolved in 100 mL of solvent.

Source: References 7.1, 7.12, and 7.13.

7.5 MISCELLANEOUS ANALYSES BY WET CHEMICAL AND OTHER METHODS

This section summarizes a variety of wet chemical and other procedures which will be used to analyze various species in FGC waste solids and liquors, groundwater, and surface water samples.

Detailed procedures are given in the following references and and exhibits:

Sample	Analyte	References
Ash slurry liquor	pH	Exhibit D.5-1
	Total Dissolved Solids (TDS)	Exhibit D.5-2
Ash/FGD waste liquor	pH	Exhibit D.5-1
	Total Oxidizable Sulfur (TOS)	Exhibit D.5-3
	Hydroxide (alkalinity or acidity)	Exhibit D.5-4
	Carbonate (alkalinity)	Exhibit D.5-5
Ash/FGD solids	Acid Insolubles	Exhibit D.5-6
	Total Oxidizable Sulfur (TOS)	Exhibit D.5-3
	Sulfate ($SO_4^=$)	Exhibit D.5-7
	Hydroxide (alkalinity)	Exhibit D.5-4
	Carbonate ($CO_3^=$)	Exhibit D.5-5
Groundwater/surface water	Sulfite (SO_3)	Exhibit D.5-3
	pH	Exhibit D.5-1
Groundwater/surface water	Total Dissolved Solids (TDS)	Exhibit D.5-2
	Conductivity	Reference 7.14
	Carbonate ($CO_3^=$)	Exhibit D.5-5
	Hydroxide (alkalinity, acidity)	Exhibit D.5-4

Procedures for measurement of boron and silicon using dc plasma emission (Ref. 7.15) and fluoride/chloride using ion selective electrode are also included. (Ref. 7.16 and 7.17.)

7.5.1 Total Oxidizable Sulfur (TOS)

Measurement of TOS at high concentration in solid and liquid samples will be made by reaction with iodine and titration of excess iodine with thiosulfate. Trace levels of sulfite will be measured using a modified West-Gaeke (colorimetric) procedure. These procedures are detailed in Exhibit D.5-3.

A newly developed technique using ion chromatography will be evaluated to determine comparability with the above techniques.

7.5.2 Sulfate ($SO_4^=$)

Sulfate in solid samples (FGD) will be determined by addition of excess lead to the solubilized sample and determination of the excess lead using a back-titration with sulfate or by ion chromatography. Measurement of sulfate in liquid FGC wastes will be made by oxidation of all sulfur species with H_2O_2 and determination of total sulfate by IC. Sulfate will then be determined by difference of any sulfite (TOS) originally present. These procedures are detailed in Exhibit D.5-7.

7.5.3 Carbonate ($CO_3^=$)

Carbonate in FGD solids will be measured by evolution as CO_2 (after oxidation of $SO_3^=$ to $SO_4^=$) and collection in an impinger filled with NaOH solution. Carbonate in the solution is then determined by titration. The procedure is detailed in Exhibit D.5-5.

7.5.4 Alkalinity/Acidity

Alkalinity or acidity of various solid and liquid samples will be determined by titration with acid or base using various indicator solutions. The procedures are detailed in Exhibit D.5-5.

7.5.5 Total Dissolved Solids (TDS)

Total dissolved solids in various liquid samples will be determined by drying an aliquot to constant weight at 120°C. The procedure is detailed in Exhibit D.5-2.

7.5.6 Acid Insolubles

This procedure will be used to determine an approximate ratio of ash to FGD material present in a mixture of the two. The procedure determines the amount of sample which is insoluble in 1 N HCl. The procedure is detailed in Exhibit D.5-6.

7.5.7 pH

Measurement of pH will be made on liquid and slurry samples using glass and reference electrodes. This method is detailed in Exhibit D.5-1.

7.5.8 Conductivity

Measurement of conductivity will be made using commercially available instruments (i.e., YSI Model 33 SCT meter). The procedure which will be utilized is detailed in Reference 7.14.

7.5.9 Boron/Silicon

Analysis of boron and silicon in solids will be performed directly or after fusion with Na_2CO_3. Dissolved solid and/or liquid samples will be analyzed directly by emission. The recommended procedure for fusing solids is 0.1 g with 1 g Na_2CO_3 and dissolution in 1 N HCl. (This procedure needs to be tested for FGC materials.) Alternate fusion techniques will be used as discussed in Section 5 in conjunction with the dc plasma emission technique. An alternate colorimetric analysis using curcumin reagent will be used if samples cannot be analyzed by emission. Details are given in Reference 7.15.

7.5.10 Fluoride and Chloride

For solid samples such as ash and FGD materials, measurement of fluoride and chloride may be made after total dissolution of the sample and using an ion selective electrode. For fluoride, the sample will be analyzed by HF evolution and measurement of the collected fluoride measured by ion selective electrode as in Reference 7.17. Altenatively the fluoride collected can be analyzed by ion chromatography. Chloride analyses for solids will be performed as in Reference 7.16.

7.6 RADIOACTIVITY

The disposal area will be sampled and analyzed for active nuclides in several areas in order to assist in evaluation of the potential environmental impact of disposal of FGC waste with regard to off-site transport of radioactive substances. These areas may include (in order of priority).

a) Waste samples,
b) Liquors and leachates, and
c) Radon emanation from area.

Samples associated with these areas include:

- Waste -- ash and FGD solids,
- Liquors -- sluice liquors accompanying waste,
- Leachates -- extract samples from solids, groundwater, and surface runoff (background and downgradient), and
- Emanation -- radon gas emanation from the site and off-site as background.

Initially, it is proposed to sample and characterize the radioactive nuclide content of samples of the solid phase from the site and currently disposed influent solid materials as a first step to assessing if further analysis is required. Performance of additional tests is contingent upon determination of the need to do so, which will be based on assessment of previous results.

The discussion and methodology described below covers procedures which can be employed if necessary for analysis of all of the listed samples. Materials will be sampled and analyzed according to the following typical matrix:

Sample	Number	Analyte
Influent Solid	3	^{226}Ra
Solid in Site	9	^{226}Ra
Influent Liquor	to be determined	^{226}Ra, ^{228}Ra, total a, total B
Liquor Phase in Site	to be determined	^{226}Ra, ^{228}Ra, total a, total B
Extract of Waste	to be determined	^{226}Ra, ^{228}Ra, total a, total B
Groundwater/Surface Water	to be determined	^{226}Ra, ^{228}Ra, total a, total B

Radon Flux from Site to be determined ^{222}Rn (gas)

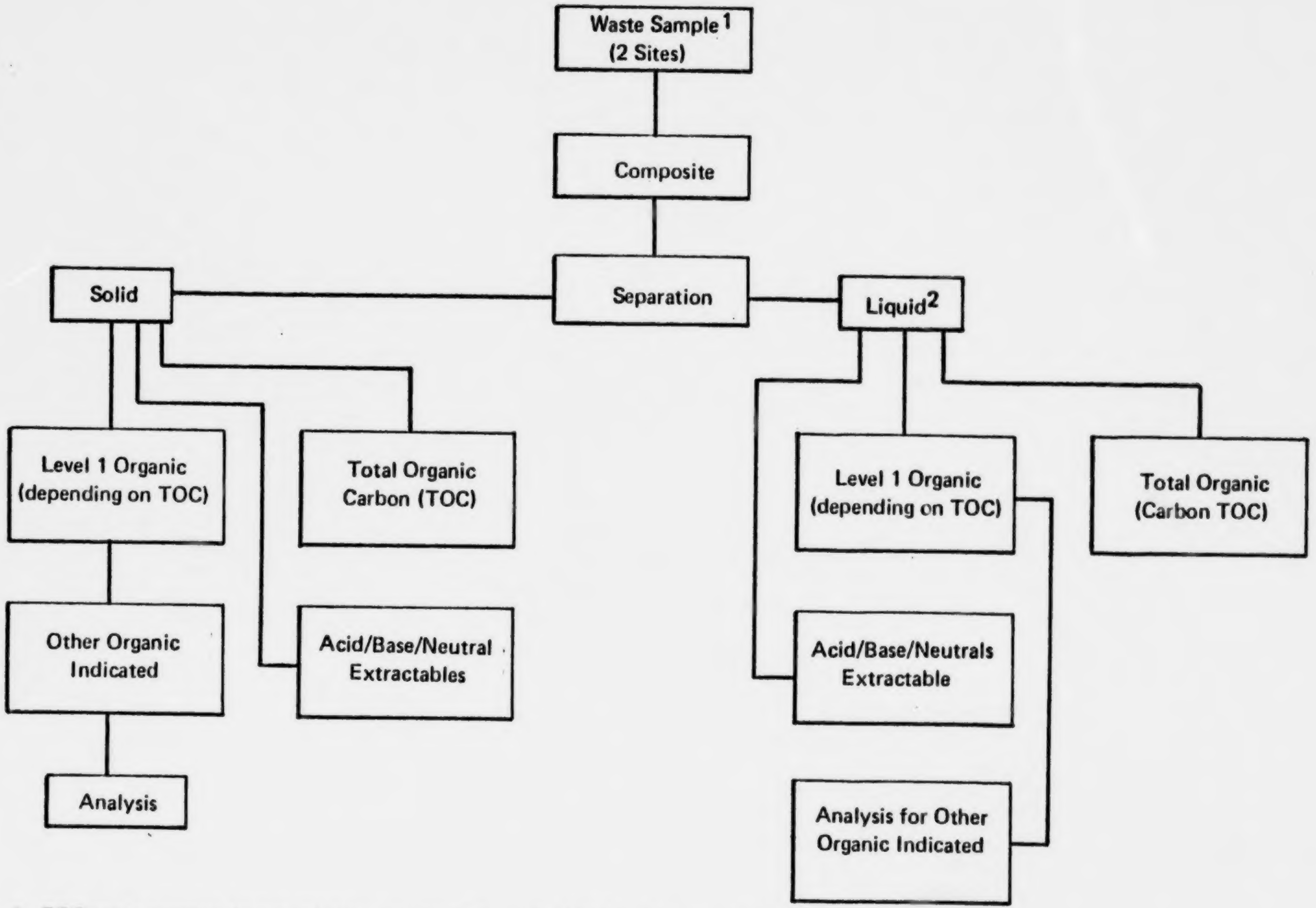
The methods to be used to characterize the radioactivity in the listed samples are given in References 7.20 through 7.24 and briefly described in Exhibit D.6-1.

Radioactivity in the solid samples will be characterized by the ^{226}-Ra concentration using either the Radon Emanation technique (Ref. 7.20) or Gamma Ray Spectroscopy (Ref. 7.21). Radioactivity in liquid samples will be characterized by analysis of ^{226}Ra, ^{228}Ra, total alpha, and total beta. Radium 228 will be determined by barium coprecipitation and beta particle counting (Ref. 7.22). Radium 226 will be determined by barium coprecipitation and alpha particle correcting. Total gross alpha and beta will be determined by drying the liquid samples and using gas flow through proportional alpha and beta counters (Ref. 7.23). Rn^{222} flux at and off the site will be measured using canisters filled with activated charcoal and measuring the accumulated gamma ray activity in the canister using a detector (Ref. 7.24).

7.7 ORGANIC ANALYSIS OF FGC WASTES

A limited number of organic analyses will be performed on FGC waste samples as an initial screening, and if the presence of organic substances of interest is indicated in the waste solids or liquors, the extent of organic analyses will be expanded and will also include some groundwater and/or surface water samples. A summary of the initial organic sampling and analysis approach is given in Figure 7.9. Performance of additional tests will be contingent on the need to do so based on these results.

The Level 1 Organic procedures and the priority pollutant analysis approach (Acid/Base/Neutrals Extractables) are given in References 7.23, and 7.24. Some investigators have indicated the possible presence of dimethyl and monomethyl sulfate in FGC wastes. If possible a few samples will be screened for these substances. As part of this screening approach a Level 1 Inorganic scan will also be performed (Ref. 7.25). Procedures for total Organic Carbon Analysis are given in Reference 7.26.


Waste Sample[1]
(2 Sites)
Composite
Separation
Solid
Liquid[2]
Level 1 Organic
(depending on TOC)
Total Organic
Carbon (TOC)
Other Organic
Indicated
Acid/Base/Neutral
Extractables
Analysis
Level 1 Organic
(depending on TOC)
Total Organic
(Carbon TOC)
Acid/Base/Neutrals
Extractable
Analysis for Other
Organic Indicated

1. FGC waste samples do not contain any pesticides or herbicides, thus these are not analyzed.
2. Applicable also to groundwater samples (excluding Level 1 Organic).

Source: Arthur D. Little, Inc.

FIGURE 7.9 SUMMARY OF ORGANIC ANALYSIS APPROACH[1]

7.8 DOCUMENTATION OF LABORATORY ACTIVITIES

7.8.1 Laboratory Chain-of-Custody Procedures

At the laboratory, all samples will be received by the laboratory custodian, or a specifically designated trained alternate. The custodian will sign and date the shipment waybill, inspect the packages for evidence of tampering, and then open the packages to examine the contents. The custodian will first verify that the information on the sample labels matches that on the packing list enclosed with the samples. Then the custodian will log in all samples by assigning laboratory identification numbers in ascending sequence, every sample having a unique, non-recurring laboratory number. The Laboratory Log Notebook will include the field number, date of receipt, condition of sample when received, a qualitative description, the assigned laboratory number, sample preparation required (spiking, etc.), sample distribution, and any other information deemed appropriate. The sample custodian will be responsible for preparing and introducing control samples, blanks, and check standards.

Samples will be kept in a locked container (refrigerated, if necessary, for sample preservation) when not being analyzed. Sample distribution sheets (e.g., one per lot of ten samples) will accompany the samples as they progress through analytical procedures. These sheets will supplement the data given in Laboratory Log Notebooks.

7.8.2 Laboratory Log Notebook

In keeping with good scientific laboratory practice, each analyst will keep a Laboratory Log Notebook in which all procedures performed and results obtained are recorded. Standard procedures may be indicated by reference to the appropriate document; however, any deviations will be recorded in detail. For experimental results which will be calculated from raw data, the raw data, means of calculation, and final calculated results will be recorded in the notebook. The analyst will review, sign, and date each page of the notebook daily.

Information will be recorded in the Laboratory Log Notebook so as to permit the analyst to reconstruct at a later time exactly what procedures were followed. The project analytical supervisor will review each analyst's notebook with him/her weekly to ensure completeness, clarity, and verification of procedures.

8.0 QUALITY ASSURANCE/QUALITY CONTROL

The sampling and analysis Quality Assurance/Quality Control (QA/QC) program for this project will ensure that all sampling and analysis information collected and reported is valid and complete, and sufficiently precise and accurate to meet end-use requirements. The QA/QC program will verify that the data generated by project personnel meet all the established criteria. As applied to the sampling and analysis portion of the project, the QA/QC program will include in-house Arthur D. Little, Inc. activities and the activities of associated subcontractors. The program will cover site development, sampling, analysis, data processing and handling, and all supporting activities in these areas.

The QA/QC program will be integrated and will ensure that all procedures will include provisions delineating the practices, requirements, and procedures which are to be implemented at each phase of the program for all participants and subcontractors.

The QA/QC program will be implemented at two levels:

1. **Quality Assurance Level**

   Activities at this level monitor the development of experimental data goals and the design and implementation of QC procedures. QA personnel determine that QC procedures are being followed and that corrective action is being taken when necessary. Finally, the QA function ensures that the level of uncertainty inherent in the experimental data is communicated to the ultimate recipients of the data.

2. **Quality Control Level**

   This level includes all activities carried out by program technical personnel to determine data precision and accuracy, comparison with previously defined goals, and taking corrective action if goals are not being met.

The fundamental components of the QA program will be common to chemical sampling, analysis, hydrologic exploration, and physical testing. The QC procedures which are used to track performance will differ depending on the sort of sampling, analysis, or testing which is being performed. Chemical analyses will rely heavily on the use of calibration standards and experimental determinations of instrument response characteristics. For physical testing, the QC procedures will be based on careful adherence to established, well-characterized protocols and on careful calibrations of fundamental measurements of mass, pressure, displacement, and volume.

The Arthur D. Little, Inc. Project Director, Mr. C.J. Santhanam, has overall responsibility for QA/QC activities associated with this project. Oversight and advice with regard to QA/QC of physical sampling and analysis will be provided by Dr. D. Joseph Hagerty of the University of Louisville. Dr. James E. Oberholtzer of Arthur D. Little, Inc. will be responsible for QA/QC relating to all chemical sampling and analysis activities. Dr. Hagerty and Dr. Oberholtzer will report to Mr. Santhanam on their respective areas in this project.

The following two sections present a general discussion on the QA and QC activities which will be carried out in this program. Detailed recommendations for physical and chemical sampling and analysis are contained in the two final sections.

8.1 OVERVIEW OF QUALITY ASSURANCE/QUALITY CONTROL ACTIVITIES

8.1.1 Quality Assurance

8.1.1.1 Personnel Training

In a general sense, QA for the sampling and analysis program will be provided by evaluating the possible options and selecting the optimum procedure early in the sampling and analysis program. Preferred practices will be emphasized in training sessions, provided in procedures and instructions, and ensured by the establishment of minimum standards for facilities and equipment operation, procurement and control of supplied data, and sample/data accountability. Training will be oriented to a critical view of all procedural steps, including data recording and transmittal which are necessary to obtain the desired quality.

Administrative QA investigations will include determinations of whether or not subcontractor project personnel are fully cognizant of the provisions of this manual. Additionally, administrative QA activities will be designed to determine whether or not supervisors have ascertained that all personnel are qualified for the field exploration, field testing, and laboratory testing activities to which they have been assigned.

Quality Assurance managers and advisors have assumed that all personnel employed in field and laboratory activities are qualified by experience and education to undertake and complete the work that is assigned to them by their respective project managers. The technical personnel assigned to field exploration activities or laboratory testing activities should receive intensive and extensive training in the sampling and testing procedures described in this manual. Additionally, supervisory and administrative personnel assigned by the subcontractor to work on this project must be familiar with the provisions of this manual with regard to QA and QC, and they must make every effort to comply with these provisions during the entire progress of the study. Further education and indoctrination of subcontractor personnel with regard to QA and QC for physical testing activities may be required. This indoctrination could take the form of periodic lectures, discussions, and seminars conducted by personnel of the subcontractors, as well as by externally originated consultants and experts.

8.1.1.2 Review of Procedures and Their Documentation

A careful review of all field and laboratory procedures being considered for the program will be performed prior to their implementation. This review will ensure that the methods chosen are appropriate for the program needs, ensure that descriptions are sufficiently complete and unambiguous so that they can be carried out consistently and uniformly, and ensure that adequate QC procedures are written into the methods so that reliability of the analytical results can be tracked.

8.1.1.3 Sample Identification and Traceability

Because of the size and complexity of this program, the volume of data points generated, and the test duration, a sample identification system will be established to provide traceability of all data. A tentative system is discussed in Section 4.11.

8.1.1.4 Review of Quality Control Procedures

Continued QC is essential to the success of this program. The adequacy of the QC program will be regularly reviewed; QA will subsequently verify the continued effectiveness of QC in these areas.

8.1.1.5 Auditing

Audits will be performed by the apropriate QA personnel responsible for either physical or chemical S/A on all aspects of the program, including field testing, sampling, and analysis. The audit effort will include random audits, suspect item audits, and problem audits within the constraints of the program. The auditing effort can consist of unannounced visits by QA personnel to inspect field or laboratory operations in progress or possibly involve scheduled discussions of planned procedures prior to implementation or of experimental results after they have been generated.

8.1.1.6 Review of Final Results and Conclusions

As the program progresses and conclusions are being drawn, QA personnel will endeavor to see that the uncertainties inherent in the experimental data are understood and taken into account.

8.1.2 Quality Control

Quality Control, as discussed in this section, is that part of the quality program which is internally applied to program activities. "Internally" means that the quality controls are implemented within the performing organization. However, the quality control guidelines, rules, methods, inspections, and limits of acceptability used in the program will be approved by QA personnel and audited as part of the QA function.

The manual is to be followed explicitly. If deviations are required, these must be documented and reported. Any changes will be approved by the QA officer and distributed to all parties concerned as addenda to this manual. Through study and demonstrated appropriateness, acceptable revisions to procedures can be developed, which in turn will represent a new set of controlled conditions. The guidelines to be used in the sampling and analysis program training, manual, facilities, etc., are provided below.

8.1.2.1 Facilities, Equipment, and Supplies

All equipment will be calibrated on a regular basis as per protocol for the individual instruments. The laboratories will be neat and orderly, within appropriate limits imposed by the nature of the operation. Laboratory benches, particularly areas where critical operations such as weighing or transfer are carried out, will be kept clear of all but necessary tools, glassware, and other equipment.

Well-defined and documented purchasing guidelines for all equipment and reagents having an effect on data quality will be used. Only chemicals and solvents of known purity with certified analyses will be used. Each procedure will dictate the purity level of special solvents as required. Performance specifications for all critical items of equipment will be reviewed initially to assure that the equipment is satisfactory for the purpose intended.

Materials of construction and cleaning procedures for sampling apparatus, sample containers, and laboratory apparatus will be specified to minimize contamination.

8.1.2.2 Documentation Control

Any procedural changes will be documented and a clear, defined method for document revisions will be established. A revision will be prepared by the appropriate technical coordinator, e.g., chemical sampling or physical testing and submitted to the QA officer for approval and distribution. This will include informing all involved personnel of the updated procedures and distributing copies of updated procedures to each person on the program, thus assuring that the change is implemented and permanent. It should be understood that revised procedures supersede previous ones, unless specific alternative choices are specified.

8.1.2.3 Calibration Procedures

The quality of any data is no better than the accuracy of the calibration of the instrument or apparatus. For instruments or apparatus which are empirically calibrated, every calibration curve should have at least three points, one of which is higher and one of which is lower than that of the sample. A calibration curve with only one or two data points is valid only if it has been verified that the calibration is intimately associated with the nature of the test and accuracy requirements, and should be presented as part of the procedure. In general, calibration should be made at a sufficiently frequent interval so that zero drift, gain changes, reagent degradation, or other time-associated changes do not contribute significantly to the overall variation of the method.

Detailed calibration procedures for each method to be used are being developed in conjunction with method qualification studies and will be issued as addenda to this manual.

8.1.2.4 Monitoring Precision and Accuracy

To document that reproducible results are being obtained (i.e., precision of the method), duplicate samples will be run. Although the frequency of such check analyses is, by nature, dependent on such factors as the original precision of the method, the reliability of the instrumentation involved, and the experience of the analyst, good laboratory technique is to run duplicate analyses a minimum of ten percent of the time. In this program, at least one sample in ten analyzed will be either a field or lab duplicate. The resulting data should agree favorably with the known precision of the method. Otherwise, the analyst will troubleshoot the system to determine the discrepancies. The QA coordinator will specify which specific samples are to be run in duplicate by the various analysts.

Concurrently, QC also monitors the accuracy of the measurement method. It is preferable to obtain values compared to known standards; however, a measurement of the response of a chemical analysis method to additive known amounts of the species is also very valuable. As a matter of routine practice, spiked samples will be used as a quality measurement. Appropriate spiking frequency is dependent on the analytical procedure and the nature of the sample matrix. It is not appropriate to specify an exact spiking frequency at this time; however, it is envisioned that about 10% of all samples will be spiked. Spiked samples will be run on samples specified by QA personnel.

In the area of physical testing, it is difficult to assess accuracy based on measurements of standards. In this area, accuracy is more often determined by fundamental metrological calibrations, e.g., mass or displacement, and by careful adherence to standard procedures.

8.1.2.5 Feedback and Corrective Action

Of utmost importance is the mechanism for reviewing data, problem detection, reporting, and corrective action. The responsibility shall lie essentially with each analyst and the respective analytical coordinator to review the data and decide which data may be suspect. The field sampling coordinator will play a similar role in the sampling area. The QA officer will meet regularly with each coordinator to review and approve any suggested corrective actions.

8.2 QUALITY ASSURANCE AND QUALITY CONTROL ACTIVITIES FOR PHYSICAL TESTING

8.2.1 Introduction and Summary

The quality assurance/quality control (QA/QC) activities related to physical testing shall consist primarily of:

- Activities which are essentially internal to each of the organizations performing field and laboratory physical testing and evaluation, and
- Activities which are external to the two subcontractors performing the actual work.

QC will be the responsibility of subcontractor project managers subject to overall QC by Arthur D. Little, Inc. Project engineers and geologists who will directly supervise laboratory testing, field sampling, and exploration activities have a major role in implementing QC. QA advice and oversight will be provided by University of Louisville personnel, organized to report to the Project Director, C.J. Santhanam.

In general, QC activities will be based on a heavy reliance on standardized testing procedures for the most part contained in applicable standards of the American Society for Testing and Materials (ASTM). Additionally, quality control for laboratory testing will be supplemented with a monitoring program in which samples of wastes and natural soil materials will be selected for testing at the University of Louisville, as well as at Bowser-Morner Laboratories. In essence, one of every 20 samples taken will be split with a portion retained by Bowser-Morner to be subjected to the entire suite of tests and a portion sent to the University of Louisville for check testing with respect to strength and permeability.

QA activities will extend into two primary areas, administrative QA and technical QA. Administrative QA activities will ensure that the physical testing work is done in an efficient and accurate manner with regard to the overall organization of the work, the allocation of responsibilities for the work, the procurement of supplies and services, and the meeting of schedules for various activities. Technical QA activities will be directed towards overall evaluation, monitoring and, if needed, remedial measures applicable to various technical activities such as sub-surface exploration, field sampling, field groundwater monitoring, calculations associated with field and laboratory procedures, laboratory testing methods, etc. Additionally, technical QA will involve the monitoring and evaluation of all test plans and reports drawn up under this project. Finally, procurement activities related to physical testing in this project will be evaluated in terms of the administrative quality assurance procedures mentioned previously.

8.2.2 Responsibilities

With regard to the laboratory testing, sub-surface exploration, field monitoring and evaluation, and other physical activities undertaken by the subcontractors, Bowser-Morner or Haley & Aldrich, the project managers for those subcontractors shall be considered the individuals responsible for implementation of QC measures for the various activities assigned to them. With regard to the particular operations carried out at a given power plant waste disposal site, the project manager for each of the subcontractors shall designate an individual who is a member of the field party at that site as the official QC supervisor for all activities by that subcontractor at that site. With respect to laboratory testing work, the project manager for Bowser-Morner shall delegate an individual to be responsible for QC of the laboratory testing associated with this project. These specific individuals in the subcontractor organizations shall be responsible for the control and management of field investigations, field testing, laboratory testing activities, procurement of supplies and equipment associated with these activities, and the reporting and analysis of data gathered during these activities. Additionally, these QC managers, along with the chief cost management officer for this project for each of the subcontractors, shall track and account for project costs. Finally, the QC personnel for each of the field investigation efforts and for the laboratory testing activities shall be responsible for maintaining communication with the QA advisor at the University of Louisville, the project managers at each of the subcontractors, and the Arthur D. Little, Inc. Project Director.

8.2.3 Administrative QA Activities

The administrative QA activities carried out with regard to physical testing for this project will be intended primarily to evaluate the degree of proper implementation of QC procedures by the subcontractor organizations employed in physical testing work. In other words, the administrative QA audits and investigations described herein will be designed primarily to evaluate administrative procedures for implementing QC rather than to discover technical inadequacies or deficiencies. The primary emphasis will be placed upon scrutiny of organizational methodology including the maintenance of a schedule for the work, the control and organization of all documentation associated with the work, and the plans for QC activities.

With respect to QA audits and visits directed towards investigations of administrative procedures, the appropriate personnel at the subcontractor organizations will be informed of the proposed date of an audit prior to the conduct of that audit. An audit report will be prepared by the QA advisor and circulated to all appropriate personnel. After the audit is completed and prior to the preparation of an audit report, a post-audit conference will be held with subcontractor personnel by the QA advisor. With regard to any deviations in procedures or deficiencies in physical activities, the subcontractor project manager will be required to interact with the QA advisor subject to the overall directives of the Arthur D. Little, Inc. Project Director, to identify the causes of the deficiencies or deviations, and to ensure that the deviations and/or deficiencies are properly corrected.

8.2.3.1 Liaison and Communications

Administrative QA efforts will be directed toward maintaining easy and adequate communications between subcontractors engaged in physical testing, the QA advisor, and the Arthur D. Little, Inc. Project Director for this work. Significant attention will be devoted to the control of project documents such as job specifications; descriptions of testing procedures; copies of reports, calculations and drawings; site visit reports; preliminary test plans; final test plans; and other documents associated with the physical testing work for this project.

All documents associated with this project should be clearly identified with a special code designation for this project. A document log should be maintained by the contractors engaged in physical testing to monitor the distribution and transfer of all documents associated with this project. Documents related to this project should be routed through a single individual designated for this duty by each of the subcontractor organizations. All project documents should not be released to other subcontractor organizations or to any other individuals without prior approval of the Arthur D. Little, Inc. Project Director. This restriction does not apply to informal communications such as memoranda and personal notes of an unrestricted nature; nor does it apply to records of telephone conversations, unless the subject matter of the informal communications is liable to misinterpretation or other undesirable usage after distribution to personnel outside Arthur D. Little, the University of Louisville, Bowser-Morner Laboratories, or Haley & Aldrich.

8.2.3.2 Procurement of Services, Equipment, and Supplies

In order to assure accuracy and quality in the physical testing activities carried out on this project, administrative QA restrictions must also extend to procurement of services and equipment, as well as supplies, by the subcontractors engaged in physical testing. The Arthur D. Little, Inc. Project Director assisted by the QA advisor will endeavor to establish the capability and the availability of any consultants or service organizations desired by the subcontractor before granting approval for such employment. Approval of all consultants and other contracted individuals must be obtained from the Arthur D. Little, Inc. Project Director before they are assigned work on this project.

These provisions for procurement of services shall include procurement of all contract drilling and exploration services, whether such contract drilling is procured by Bowser-Morner or by Haley & Aldrich. Before such contract drilling services are procured, a contractual statement of scope of work, schedule for work, and project responsibilities to be applied to the contract drillers would be reviewed by the QA advisor on such decisions by Arthur D. Little, Inc. Prior to the granting of approval for such work, the contract drillers' specifications for services including sub-surface explorations will be reviewed. Other items concerned with contract provisions such as insurance requirements, warranties, bonding, terms of payment, and other information will be required prior to the approval of the use of contract drillers in this project. Final approval will be granted by the Arthur D. Little, Inc. Project Director.

With respect to equipment and supplies purchased by the subcontractors for this project, the routine purchase of supplies and testing equipment for the geophysical investigations and the groundwater monitoring activities included in the scope of this project will be the responsibility, as far as QC and QA are concerned, of the project managers for the individual subcontractors for physical testing. However, the equipment and supplies used and purchased for this project, both for field testing and exploration, and laboratory testing and evaluation will be evaluated by the QA advisor as required and directed by the Arthur D. Little, Inc. Project Director.

8.2.4 Technical QA Activities

8.2.4.1 Review of Test Plans

In order to assure quality in the conduct of the physical testing associated with this study, it will be necessary in advance of any physical testing work to develop a complete plan for field exploration, field testing, and laboratory testing for each of the sites investigated. Obviously, this testing plan can be modified to suit conditions discovered on-site, but the test plan must be developed prior to the commencement of work at a particular site and must be approved by the Arthur D. Little, Inc. Project Director. Any changes to the test plan shall be reviewed by the QA advisor.

Prior to the beginning of laboratory testing work and prior to the commencement of the initial field exploration activities, scheduled audit visits to the physical testing laboratory and to at least one power plant waste disposal site will be arranged by the QA advisor. These scheduled audit visits will be designed to eliminate sources of inaccuracies or deviations from accepted procedures prior to the commencement of any physical testing activities.

8.2.4.2 Review of Field Operations

QA activities related to field operations will include attention to such matters as use of proper forms for reporting sub-surface information and the results of field tests, the submittal of daily reports from field project managers, complete and accurate compilation of drilling logs (and review of drilling logs by the Arthur D. Little, Inc. Project Director), and prompt submittal of all field documents to the subcontractor office and forwarding of such documents for review, as appropriate, by the QA advisor.

Various activities also will be evaluated such as: the classification of waste specimens and soil specimens from each site; the accurate location of all sampling sites; the sealing and labeling as well as storage of all samples taken from each site; careful handling of undisturbed samples where appropriate; proper packaging of all samples for shipment and shipment at the earliest possible date; and the submittal of a separate packing list for each shipment of samples to the subcontractor office, the QA advisor, and the Arthur D. Little, Inc. Project Director.

With regard to contract drilling operations, technical QA investigations will be directed toward ascertaining whether such contract drilling operations are being carried out in compliance with the sampling and analysis procedures contained in this manual and the site development procedures contained in Appendix A, "Hydrogeologic and Geotechnical Procedures Manual." The drilling operations and the sampling activities carried out by the subcontractors as well as by any contract drillers will be subject to continued scrutiny in areas such as the competency of personnel, the maintenance of drilling and sampling equipment, and the calibration of all field testing equipment.

With respect to groundwater monitoring and sampling, the QA advisor will, as and when directed by the Arthur D. Little Inc. Project Director, review plans for and provide advice on the installation and evaluation of groundwater wells and piezometers. Additionally, the manner of data collection and the frequency of data collection from wells and piezometers will be evaluated.

For all of these field operations, the subcontractor project manager will be expected to assist the QA advisor for this project to determine the causes of any deviation from accepted procedures or deficiencies in testing results identified. After the cause of such deviations or deficiencies has been identified, the effect of the identified errors will be evaluated, and appropriate corrective action will be undertaken by the subcontractor project manager with the assistance, where appropriate, of the QA advisor. Every effort will be made to identify any administrative or procedural problems which could hamper the performance of field exploration and testing operations and the assurance of quality in those operations.

8.2.4.3 Review of Laboratory Operations

With respect to laboratory work associated with this project, technical QA will include an investigation of the qualifications of the personnel engaged in testing activities. Also, the provisions for receiving and storage of samples will be evaluated. Samples must be received and stored in organized fashion, and complete and accurate documentation on all samples must be maintained at all times. With regard to laboratory testing equipment, technical QA investigations will be directed towards monitoring technical QC activities such as calibration and checking of instruments, documentation of such calibration, remedial measures for equipment out of calibration, etc. Furthermore, complete records of all testing procedures (data sheets, test reports, plots of test data, etc.), must be maintained and will be subject to scrutiny by unannounced audit test visits to the subcontractor laboratory by the QA advisor. If any non-conformances are observed in laboratory testing procedures, the subcontractor project manager will be expected to assist the QA advisor in identifying the cause of the non-conformance, evaluating the effects of the errors made as a result of the non-conformance, and carrying out proper action to remedy the non-conformance.

8.2.4.4 Review of Calculations and Data Presentation

Calculations for analyses and for interpretation of laboratory tests will be reviewed by the coordinator for physical testing with the individuals performing such calculations to make sure that the calculations are performed accurately and that they are subject to independent checking by competent individuals. Similarly, use of computer programs in data reduction and in the interpretation of field data will be evaluated to ascertain that all such programs have been checked by the use of sample problems, that the accuracy and reliability of the programs have been verified by subcontractor personnel, that the programs are sufficiently well-documented to provide easy and accurate use, and that evaluations obtained by the use of computer programs can be redone at a later date on the basis of existing project data contained in subcontractor files. With regard to calculations, all mathematical formulas and symbols should be referenced as to source and such symbols and formulas should be checked to see that they are applied properly. Units used in calculations must be consistent with the units given in the sources for the formulae and calculations. The arithmetic in calculations must be checked for accuracy. If any deficiencies or discrepancies are encountered in checking calculations, the cause of such discrepancies must be identified and the effects of such errors must be evaluated. When the results of literature searches, site visits, design calculations, or laboratory experiments are reported, every effort must be made to make sure that figures, data plots, summaries, and tables are correct as well as complete. Any changes or revisions made in original documents must be transferred to copies and must be checked for accuracy. All interpretations and recommendations must be checked with applicable codes of practice for consistency.

8.2.5 QC Activities

QC on this project with regard to physical testing and field exploration will be accomplished primarily through reliance on standard procedures and methods widely accepted in geotechnical engineering practice. Primary emphasis will be placed on compliance with the provisions of ASTM Standards as described in Appendix A, "Hydrogeologic and Geotechnical Procedures Manual," and in other sections of this sampling and analysis manual. If a situation arises in which one of the procedures outlined in either of these manuals is considered by a subcontractor organization to be inappropriate or not strictly applicable, acceptable state-of-the-art methods may be substituted as appropriate for the listed procedure, but only after appropriate consultation with the QA advisor for physical testing for this project and approval by the Arthur D. Little, Inc. Project Director. Reliance will be placed on the manuals for laboratory procedures and field procedures which have been developed by Bowser-Morner and Haley & Aldrich, and which are used by personnel of those organizations to maintain routine QC on projects.

In addition to the activities mentioned above, a further effort at QC will be made through check testing of samples at the University of Louisville Civil Engineering Laboratories. One sample in every 20 samples of FGC wastes and natural soil material will be selected by the testing personnel to be split, with a portion of the sample forwarded to the University of Louisville and a portion of the sample retained for routine testing by the subcontractor organization. The split sample will furnish a basis for evaluation of testing techniques carried out by the subcontractor. The testing activities of greatest concern in this monitoring effort will be the determination of material permeability and strength.

8.3 QUALITY ASSURANCE AND QUALITY CONTROL ACTIVITIES FOR CHEMICAL SAMPLING AND ANALYSIS

8.3.1 Introduction and Summary

Quality control (QC) in the area of chemical sampling and analysis will involve a number of activities which will be carried out by technical personnel directly responsible for field and laboratory activities. Control of quality will be maintained by first demonstrating the precision and accuracy of candidate techniques before they are applied to the analysis of real samples. Blanks, duplicates, standards, and spikes will be introduced into the sample stream throughout the duration of the program to provide a continuing measure of precision and accuracy.

Quality Assurance (QA), both administrative and technical, will be provided by personnel not directly connected with the day-to-day activities of the ongoing program. Administrative QA activities will seek to assure that the work is carried out efficiently, cost-effectively, and on schedule. Technical QA activities will include evaluations of sampling and analysis methods, test plans, the QC protocol, and the data analyses and reports generated as a result of chemical sampling and analysis activities. In addition to reviewing procedures, plans, and reports and to seeing that they also receive peer review, the individual responsible for QA/QC of chemical sampling and analysis will make unannounced audit visits to field sampling locations and to the laboratories carrying out analytical work.

8.3.2 Responsibilities

With regard to the field activities carried out to obtain samples for chemical analysis by Arthur D. Little, Inc. and its subcontractor, TRW, Inc., the responsibility for QC implementation will rest with the coordinator of field sampling in each of those organizations. For any particular sampling visit to a given power plant waste disposal site, the field sampling coordinator will designate an individual to be the field sampling team leader. The team leader will be responsible for carrying out QC activities during that visit.

Quality control of chemical analysis in the laboratories of Arthur D. Little, Inc. and the subcontractors, TRW, Inc. and Barringer-Magenta, Ltd., will be the responsibility of the analytical laboratory supervisor who will be designated at each facility.

Quality assurance related to chemical sampling and analysis will be the responsibility of Dr. James E. Oberholtzer of Arthur D. Little, Inc., reporting to the Arthur D. Little, Inc. Project Director. Subject to the direction of Dr. Oberholtzer, Mr. Ed Moon of TRW, Inc. will provide QA oversight over activities in that organization.

8.3.3 Administrative QA Activities

Administrative QA activities carried out in connection with chemical sampling and analysis will seek to ensure that the organizational structure and administrative procedures of each of the performing organizations are appropriate for carrying out the overall chemical sampling and analysis program in an accurate, timely, and cost-effective manner. Of major importance will be a determination that the chain of command set up within each of the organizations performing chemical sampling and analysis will be effective in assuring that QC activities are carried out. Quality assurance oversight over administrative activities will be exercised by conducting audit visits to the performing organizations prior to the start of work.

Another important area of administrative QA effort will involve ensuring that good communications are maintained between laboratories performing chemical sampling and analysis activities, the Arthur D. Little, Inc. Project Director, and as appropriate, individuals of other disciplines who are involved in the program. Quality assurance personnel will seek to ensure that any difficulties encountered during field sampling or laboratory analysis are communicated to the appropriate, cognizant individuals promptly. They will also ensure that procedural modifications necessary to circumvent field or laboratory difficulties are communicated to and implemented by the performing organizations on a timely basis.

To facilitate the process of transmitting analytical data from one laboratory to another and to ensure that only results whose quality has been determined are transmitted, a data manager, who shall be responsible for all transmissions, shall be designated within each of the performing organizations. Data developed during the course of this program by the contract laboratory Barringer-Magenta Ltd., shall be released to Arthur D. Little, Inc. and TRW as follows:

- In all cases, the data will be given to Arthur D. Little, Inc. directly, and
- In those cases where samples were sent to them by TRW, TRW will receive copies of data at the same time as Arthur D. Little, Inc.

Data developed by or supplied to TRW in conjunction with this program shall be submitted only to Arthur D. Little, Inc.

8.3.4 Technical QA Activities

8.3.4.1 Review of Test Plans

The test plans developed for each power plant waste disposal site to be studied will be scrutinized by QA personnel to ensure that the proposed procedures for carrying out chemical sampling and analysis are appropriate for the studies to be conducted at that site. Quality assurance evaluations will ensure that all sampling and analysis methodology has been appropriately qualified prior to its application to real samples and that an appropriate QC plan has been included in the test plan.

It is expected that difficulties will be encountered during field sampling and laboratory analysis operations from time to time. Procedures will need to be modified to circumvent such problems. Quality assurance should be notified of such problems as soon as possible after they are encountered. Proposed solutions should be reviewed with QA prior to their implementation. Clearly, there may be instances in which immediate modification is necessary to permit the continuation of sampling and analysis activities. Such changes may be made on a one-time basis; however, the QA officer should be notified as soon as possible by telephone and a formal review will be conducted before the procedural change is made permanent for future work.

8.3.4.2 Review of Field Activities

All aspects of field sampling and field measurements will be reviewed by QA on a continuing basis. Field sampling notebooks and the contents of sample shipments will be examined to ensure that data recording and documentation procedures are being followed. Unscheduled field audit visits will be made by QA personnel to view the conduct of field measurements and acquisition of samples.

8.3.4.3 Review of Laboratory Activities

All laboratory activities in the three performing organizations will be reviewed and evaluated periodically by means of unannounced audit visits. Of primary interest during laboratory visits will be a determination that prescribed QC procedures are in place and being practiced faithfully. Procedures for receiving samples, ensuring their security, and maintaining a chain of custody will be evaluated. Analysts will be observed as they perform their work, and their supervisors will be expected to review laboratory notebooks and other records with QA personnel.

8.3.4.4 Review of Data Presentation

All data, both from the analysis of unknown and QC check samples inserted by the laboratory sample custodian, will be reviewed by QA personnel to ensure that appropriate QC was practiced and that the precision and accuracy inherent in the experimental results is clearly indicated and understood by those receiving the experimental data for further interpretation. The laboratory data manager at each of the performing organizations will be expected to interact with QA personnel on an ongoing basis to facilitate this review.

8.3.5 Quality Control Activities

Program personnel involved in almost every area of sampling and analytical activities will need to concern themselves with one or another aspect of QC. Areas of activities which involve QC include:

- Analytical methods qualification;
- Acquisition of field samples;
- Compositing of samples;
- Sample digestion or other pretreatment; and
- Final analytical measurement procedures.

Recommendations for QC checks in each of the above areas are discussed in the separate subsections which follow.

The major focus of a QA/QC program is to track the precision and accuracy of the experimental data being produced throughout the program. Initial estimates of precision and accuracy for each analytical method will be obtained by analyzing replicate check samples during the method qualification phase of the program. The continuing performance of each method will be monitored by analyzing some of the same check samples and field duplicates from time to time as the program proceeds. Ideally, check samples should be similar in composition to the unknowns being analyzed, and the concentrations of the constituents of interest should have been determined by a number of analytical procedures to verify their accuracy. Standard reference materials available from NBS, EPA, and other sources are well-characterized; however, their gross compositions sometimes do not match those of the unknown samples very well. In such cases, a single pooled check sample can be analyzed repeatedly throughout the program to provide a measure of analytical precision with a realistic sample matrix.

In this program we propose to use both standard reference materials and pooled samples for QC purposes. During method qualification both types of samples will be analyzed -- standard reference materials to check accuracy and pooled samples to check precision with more realistic matrices. Subsequently, when unknown field samples are being analyzed, pooled check samples will be reanalyzed periodically to ensure that method performance does not change.

Standard reference materials which are recommended for use in this program include NBS fly ash, NBS trace mercury in water, EPA trace metals in water, and perhaps NBS river sediment. Since a realistic pooled sample would not be available until after a number of sites have been sampled, Arthur D. Little, Inc. will prepare synthetic "pooled" check samples for use by both TRW and Arthur D. Little, Inc., as well as for submission to Barringer-Magenta. Arthur D. Little, Inc. will prepare a representative FGC waste check sample from a quantity of high-sulfite, FGC sludge solids which contain fly ash. Pooled groundwater samples will be prepared by combining several samples of groundwater available to Arthur D. Little, Inc. into a single sample. The sample will be spiked at low levels with the substances of interest in the groundwater measurement protocol to ensure that they are present at detectable concentrations. One portion of that material will be acidified to stabilize the trace metal content, one portion will be left unchanged for anion and wet chemical parameters, and a third portion will be packaged separately for use as a trace mercury check.

8.3.5.1 Procedures for Qualifying Analytical Methods

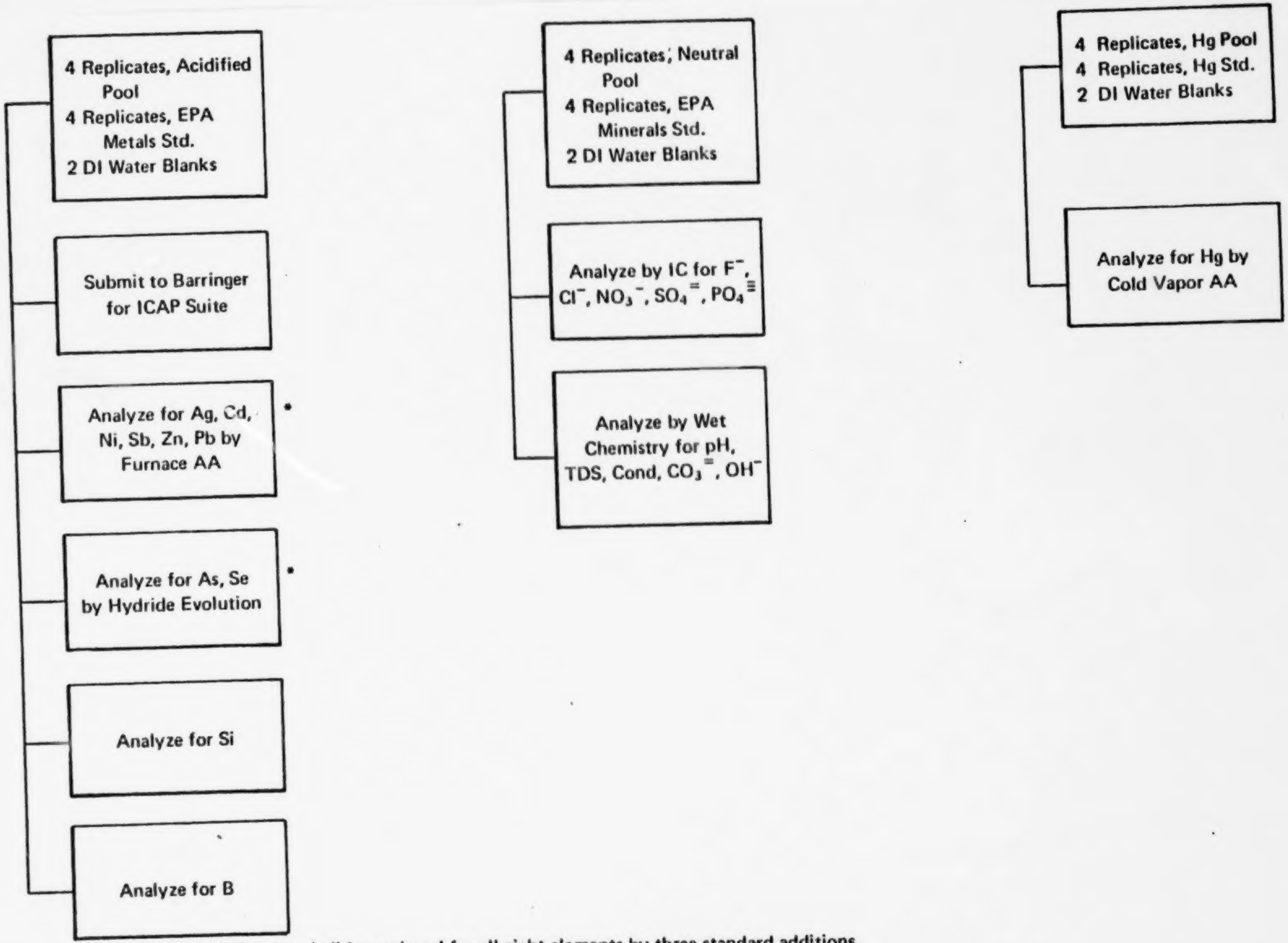
Method qualification is actually the last step in the process of bringing a new analytical method on-line. Since the results of the qualification analyses provide the point of departure for tracking the performance of the methods during the ongoing program, the qualification analyses of check samples should be performed only after the analysts are thoroughly familiar with the methods and have practiced them on samples of known composition and have found them to be working well.

The general procedure which is suggested for method qualification involves analyzing a standard reference material and a pooled check sample, each in quadruplicate. Detailed procedures have been developed for the several sample types of most importance to this program -- groundwater FGC wastes (solid phase) and FGC wastes (interstitial liquors). The same final analysis method (e.g., ICAP, IC, furnace AA) will be used for samples of all three types. It is recommended that for the check samples of all three types, the final solutions which are to be analyzed for a certain parameter be brought together and analyzed as a single batch to eliminate temporal variations. The sample set should be randomized so that all four replicates of one sample are not analyzed in immediate succession. If subgroups are analyzed on different days or by different analysts, that fact should be noted.

The qualification analyses for groundwater procedures is outlined in Figure 8.1. It should be noted that one of the four acidified pooled replicates should be spiked with Ni, Sb, Zn, Pb, As, and Se at at least three different levels and the initial concentration determined by the method of standard additions to check for matrix effects in these methods. Arthur D. Little, Inc. will spike one of the pooled samples submitted to Barringer-Magenta to check for ICAP matrix effects.

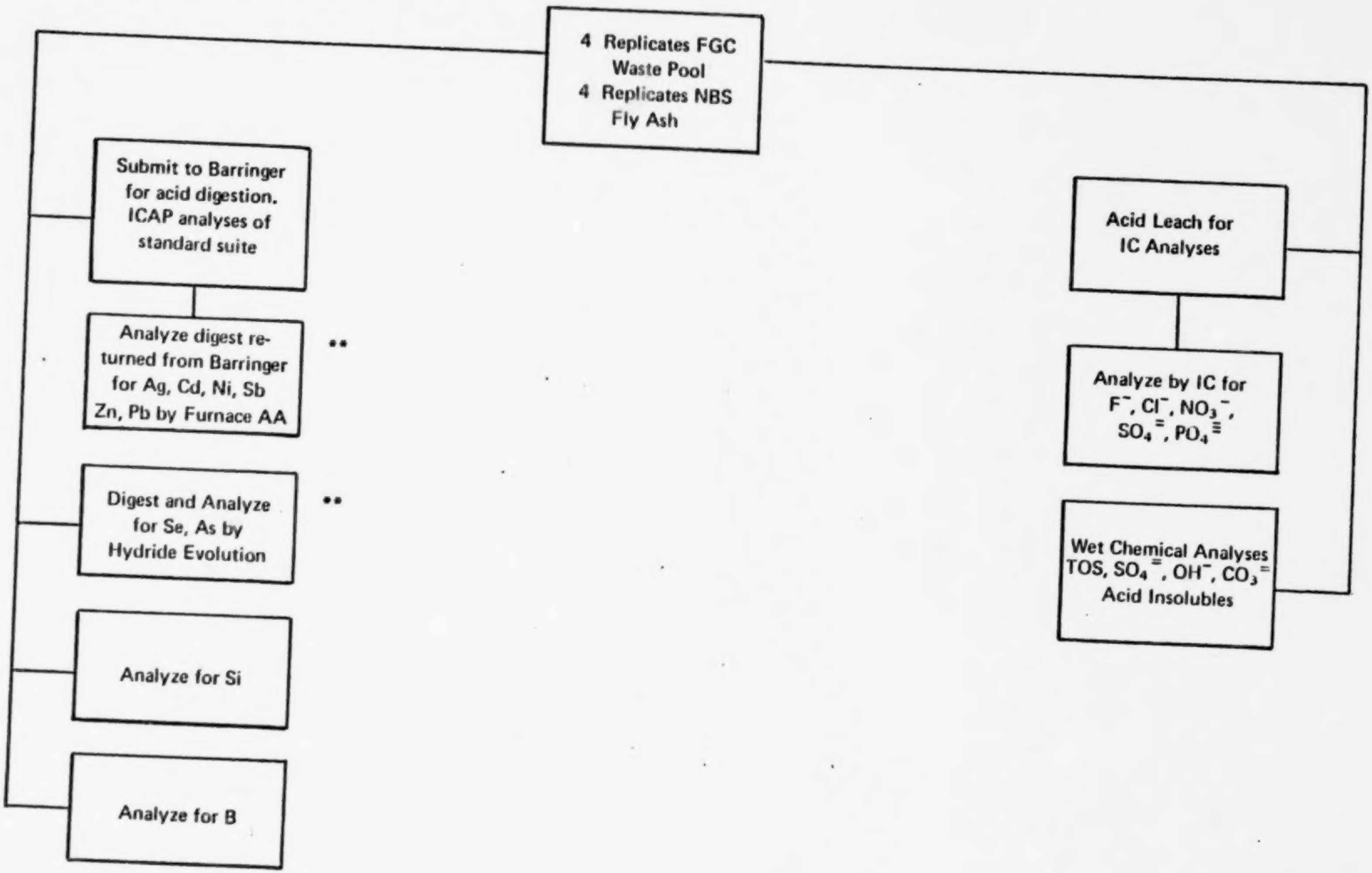
Procedures for dealing with FGC waste solids are shown in Figure 8.2. Barringer-Magenta will digest the samples sent by both TRW and Arthur D. Little, Inc. They will return a portion of the digest to each laboratory for analyses of the indicated metals by AA. Barringer-Magenta should be requested to return a portion of the digestion reagent blank as well. The levels of each of the six elements should be measured in the blank solution. As in the case of groundwater samples, AA matrix effects are to be checked by performing standard additions to one digest solution. For all parameters involving pretreatment (e.g., acid leaching) for selenium digestion, one of the final solutions to be analyzed should be split and analyzed in quadruplicate.

As shown in Figure 8.3, a surrogate FGC waste interstitial liquor is to be prepared by leaching a quantity of the FGC waste solids in twice its weight of water for 48 hours. The leaching should be done at room temperature, with stirring in a tightly


4 Replicates, Acidified Pool
4 Replicates, EPA Metals Std.
2 DI Water Blanks
Submit to Barringer for ICAP Suite
Analyze for Ag, Cd, Ni, Sb, Zn, Pb by Furnace AA *
Analyze for As, Se by Hydride Evolution *
Analyze for Si
Analyze for B
4 Replicates, Neutral Pool
4 Replicates, EPA Minerals Std.
2 DI Water Blanks
Analyze by IC for F⁻, Cl⁻, NO₃⁻, SO₄⁼, PO₄≡
Analyze by Wet Chemistry for pH, TDS, Cond, CO₃⁼, OH⁻
4 Replicates, Hg Pool
4 Replicates, Hg Std.
2 DI Water Blanks
Analyze for Hg by Cold Vapor AA

*One of the pool replicates shall be analyzed for all eight elements by three standard additions.

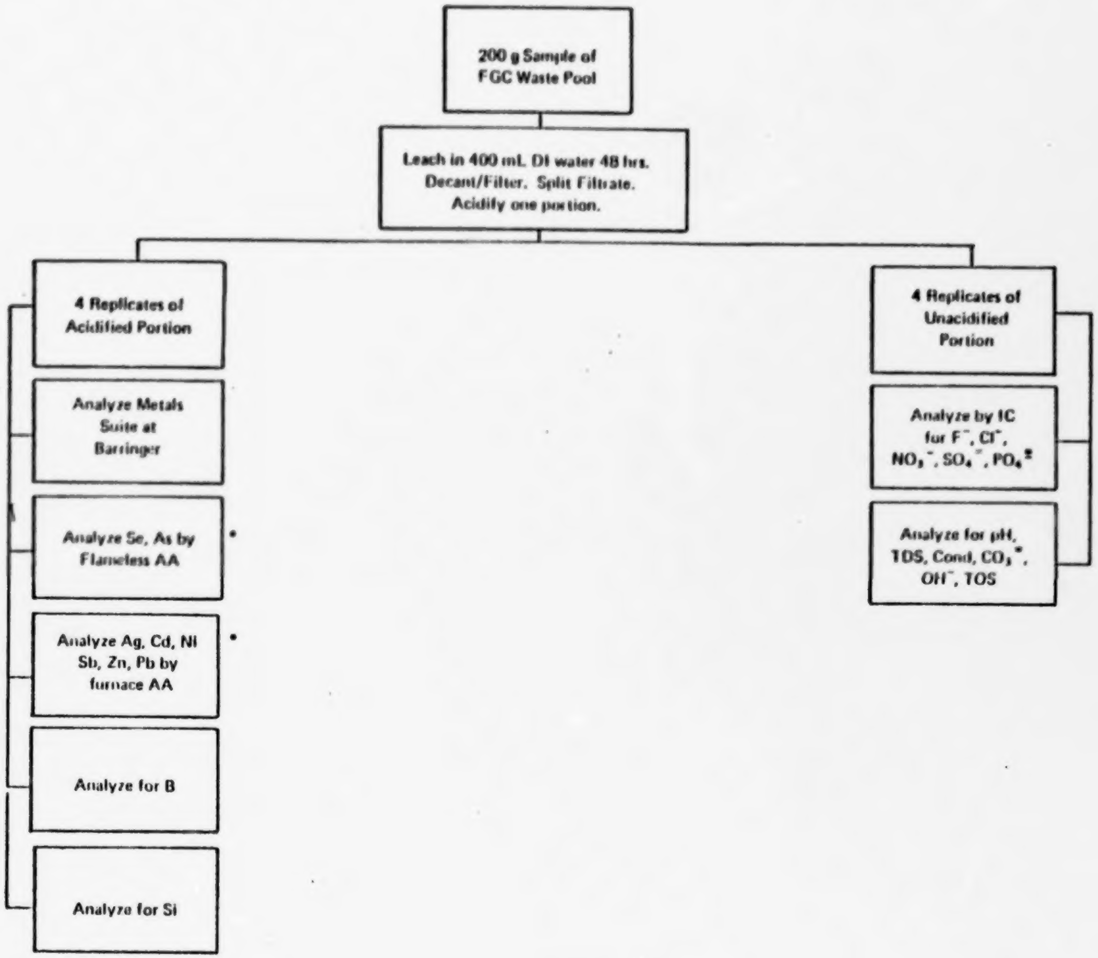
FIGURE 8.1 PROCEDURE FOR QUALIFYING GROUNDWATER ANALYTICAL PROCEDURES


4 Replicates FGC Waste Pool
4 Replicates NBS Fly Ash
Submit to Barringer for acid digestion. ICAP analyses of standard suite
Analyze digest returned from Barringer for Ag, Cd, Ni, Sb Zn, Pb by Furnace AA
**
Digest and Analyze for Se, As by Hydride Evolution
**
Analyze for Si
Analyze for B
Acid Leach for IC Analyses
Analyze by IC for F^-, Cl^-, NO_3^-, $SO_4^=$, $PO_4^\equiv$
Wet Chemical Analyses TOS, $SO_4^=$, OH^-, $CO_3^=$ Acid Insolubles

*For each analytical finish, one of the pool replicate solutions shall be split and analyzed in quadruplicate.

**One of the pool replicates shall be analyzed for all eight elements by three standard additions.

FIGURE 8.2 PROCEDURE FOR QUALIFYING FGC WASTE ANALYTICAL PROCEDURES* (Solid Phase)


200 g Sample of FGC Waste Pool
Leach in 400 mL DI water 48 hrs. Decant/Filter. Split Filtrate. Acidify one portion.
4 Replicates of Acidified Portion
Analyze Metals Suite at Barringer
Analyze Se, As by Flameless AA *
Analyze Ag, Cd, Ni Sb, Zn, Pb by furnace AA *
Analyze for B
Analyze for Si
4 Replicates of Unacidified Portion
Analyze by IC for F^-, Cl^-, NO_3^-, $SO_4^=$, $PO_4^{\equiv}$
Analyze for pH, TDS, Cond, $CO_3^=$, OH^-, TOS

*One of the pool replicates shall be analyzed for all eight elements by three standard additions.

FIGURE 8.3 PROCEDURE FOR QUALIFYING FGC WASTE ANALYTICAL PROCEDURES (Liquid Phase)

closed vessel.

For each set of four replicate results -- standard reference material, pooled sample, and replicate final measurement, when performed -- compute the mean result and the standard deviation of the mean. For the standard reference materials, compute the individual percentages recovered, the mean recovery, and the standard deviation. All individual analytical results along with the computed statistics should be submitted to the QA represenative.

8.3.5.2 Quality Control Checks During Field Sampling

Duplicates of certain of the field samples will be obtained and sent through each analytical procedure in order to track the overall precision of the analytical results produced during the sampling and analysis program. Blank samples will also be obtained and analyzed to verify that contamination of the field samples did not occur. We will aim to analyze one duplicate and one blank for about every ten samples brought from the field.

A suggested protocol for obtaining QC check samples during field sampling is shown in Table 8.1. Since each sample of groundwater or surface water will be shipped as two sub-samples -- one acidified and one unpreserved -- both of those sub-samples will be duplicated. On average, one set of duplicates per sampling visit should be sufficient. The duplicates should be taken from a different well each visit to ensure that as many as possible of the wells are duplicated during the program.

One set of blank samples should also be taken on each visit. Insofar as possible, the blank should have passed through the entire sampling process. For example, if a bailer is used, it should be cleaned ~~thoroughly~~ thoroughly with de-ionized water, and then just before sampling, it should be filled with de-ionized water and that water should be poured into the sample containers for the blank. If a filter is used, it should be precleaned and the blank sample passed through as well. If a peristaltic pump/pressure filter is employed, the entire system should be cleaned and a

TABLE 8.1

QC SAMPLES REQUIRED DURING FIELD SAMPLING

Sample	Duplicates	Blanks
Waste (Previously Disposed)	None — A duplicate of each composite will be made after compositing.	One — One extra container to be opened momentarily at site during sampling.
Waste (As Disposed)	None — A duplicate of each composite will be made after compositing.	One per sampling visit — Extra container opened while one grab sample is being taken, then closed.
Groundwater	One per visit — Both the acidified and unpreserved samples will be duplicated. Duplicate to be taken from a different well each time.	One per visit — One unpreserved sample container to be filled with the DI water used for sampler clean-up. Two acidified sample containers to be filled with DI water and acidified.
Soils	None — One duplicate for each sample will be made in the laboratory.	One for every 10 samples — Containers to be opened momentarily during sampling and then sealed.
Surface Water	One set — unpreserved and acidified.	Same as groundwater — one unpreserved and two acidified.

Source: Arthur D. Little, Inc.

quantity of de-ionized water pumped through the entire system to produce the blanks. One unpreserved blank and two acidified blanks should be obtained in this manner.

Since it will not be possible to obtain true duplicates of solid samples in the field, duplicates will be prepared in the laboratory during sample compositing. However, one blank should be taken for each solid sample type during each visit. This blank will be an empty container which is opened at the time one of the sample containers is opened; it is left open while the sample container is being filled and it is then capped when the sample container is capped.

Duplicates and blanks will be indicated by circling the appropriate code on the pre-printed sample labels.

8.3.5.3 Preparation of Duplicates During Compositing

Since it is impossible to obtain a true duplicate sample of solids in the field, duplicate solid samples will be prepared in the laboratory during the final sample size reduction which will be performed on both individual samples or composites of a set of samples. It is recommended that at least one duplicate of each sample or composite sample be made and retained for possible analysis.

For samples that are dried and finally riffled, the duplicate sample should be taken after the last riffling step. For wet solids that are sampled by thiefing, both the original sample and the duplicate should be prepared by combining a number of individual thiefed portions. Both the original sample and the duplicate should be prepared from sub-samples which are as representative as possible of the contents of the container.

8.3.5.4 Quality Control of Sample Digestion

For essentially all of the analyses which will be performed on solid samples, some sort of sample pretreatment, i.e., digestion or leaching, will be performed to obtain a solution which is finally analyzed. Each of those sample preparation procedures needs to be monitored to ensure that the substances of interest are being quantitatively extracted, that they are not being lost in the process, and that impurities are not being introduced in the reagent used in the preparation. To that end, it is recommended that for every batch of twelve or less samples subjected to a sample preparation procedure, one additional sample of the pooled check sample analyzed during method qualification be passed through the procedure and the resulting solution analyzed. In addition, one reagent blank should be processed for each lot of samples prepared in order to detect contamination introduced by the reagents used. A blank should also be included whenever a reagent from a new lot not previously used is introduced. Since this program involves a large number of similar procedures, it is strongly recommended that substantial quantities of the reagents to be used -- acids in particular -- be acquired at the outset of the program and checked for purity prior to their use in any procedures.

8.3.5.5 QC of the Final Analysis Step

The final step in the sampling and analysis sequence is the measurement of the concentration of the substance of interest by an instrumental or classical method -- the so-called "analytical finish." The prime reponsibility for QC of this very important step in the S/A process is in the hands of the analysts actually performing the analytical finish. The identity of the field and sample preparation QC check samples will not be known to the analysts, so that the results from those analyses can be used by the QA representative to independently monitor overall sampling and analysis precision and accuracy. However, each day the analyst will run his own QC check samples, and he himself will determine whether his measurement method is in control. If it is out of control, he will stop immediately, inform the laboratory analytical supervisor, and seek to correct the problem before proceeding.

The first important responsibility of the analyst is to accurately calibrate the measurement method to be used. For measurement techniques like AA and IC which produce responses proportional to concentration, a calibration curve must be developed from at least four points encompassing the range of concentrations likely to be encountered in the unknown sample. A new calibration curve should be generated each time a particular method is set up for a group of samples. If a particular analysis of one group requires more than a single day to complete, a complete calibration curve may not need to be generated if the single-point calibration check described below produces a response within 5% relative of that obtained when the calibration curve was determined. If concentrations greater than the highest calibration point are found during the course of running unknown samples, those samples must either be diluted and reanalyzed, or the calibration curve must be extended to encompass all of the higher concentrations by analyzing one or more standards.

For analytical methods which are inherently stoichiometric, e.g., titrimetric TOS, alkalinity, and carbonate, the titer of the reagents should be checked daily.

After the analytical instrument has been calibrated and the analysis of unknowns has begun, the analyst must introduce a QC check sample into the sample stream at regular intervals to ensure that the method continues to perform acceptably. Three types of check samples are useful and should be included -- a duplicate of one of the unknowns, a reagent blank, and a calibration check. It is recommended that as a minimum one of each of these types of check samples be run for each group of 30 or less samples analyzed. If analysis of a lot of 30 or less requires more than one day, one each of the check samples should be run on each of the days.

The calibration check serves to detect drift in instrument response. If analysis of a group proceeds over more than one day, the calibration check should be the first analysis run at the beginning of each day. If the calibration check is in error by more than an acceptable amount, the instrument must be completely recalibrated prior to proceeding with analyses. If the error is sufficiently great, all of the samples analyzed since the last successful calibration or calibration check will need to be analyzed. The action levels at which recalibration or reanalysis are required will be determined after the results of the method qualifications study have been analyzed. For many methods, it would be reasonable to assume that recalibration would be required if the check sample response was in error by more than 5% relative, and reanalysis would be required if the error was greater than 10% relative.

Another measure of precision is provided by analyzing one of the unknown samples in duplicate. The duplicate analyses should not be performed one after the other but rather separated by at least one-third of the samples in the lot. Again, the action levels for trouble-shooting the method and then continuing or trouble-shooting and then going back and reanalyzing will be determined at the end of the method qualification process. In many programs of this sort, a deviation between a replicate pair exceeding twice the historical standard deviation of the method on replicates is taken as a warning, and a deviation in excess of three times the standard deviation of the method on replicates is a signal to stop, correct the problem, and reanalyze. Similar criteria for acceptable behavior of the reagent blank which is run periodically will also be developed at the end of the qualification program.

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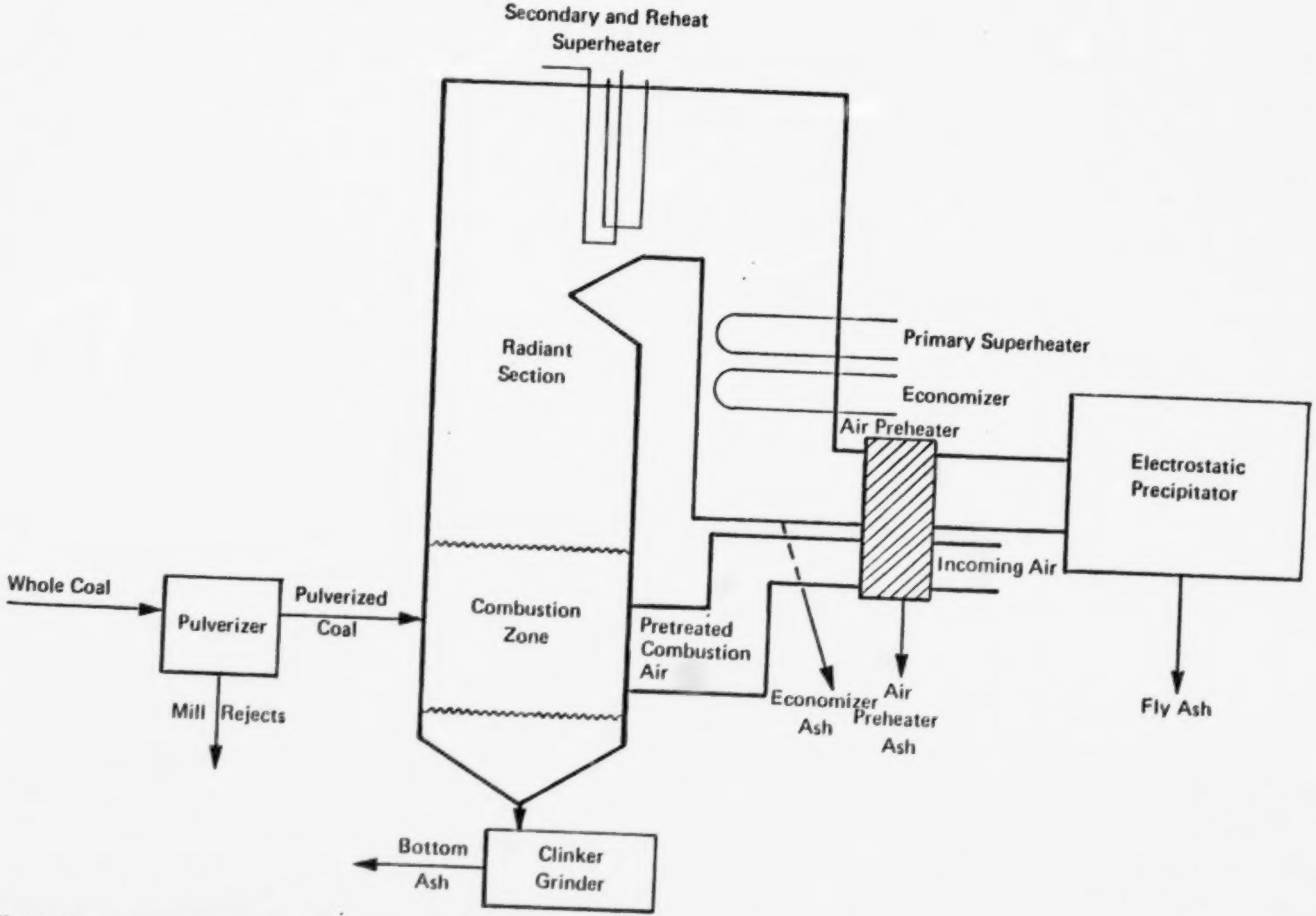
EXHIBIT A.1-1

VARIETY OF ASH AND OTHER WASTE PRODUCED IN COAL COMBUSTION


Secondary and Reheat Superheater
Radiant Section
Primary Superheater
Economizer
Air Preheater
Electrostatic Precipitator
Whole Coal
Pulverizer
Pulverized Coal
Combustion Zone
Pretreated Combustion Air
Incoming Air
Mill Rejects
Economizer Ash
Air Preheater Ash
Fly Ash
Bottom Ash
Clinker Grinder

Note: Soot may be present in all ash streams.

Source: Arthur D. Little, Inc.

FIGURE 1 VARIETY OF ASH AND OTHER WASTE PRODUCED IN COAL COMBUSTION

EXHIBIT A.5-1

GROUNDWATER SAMPLING BACKGROUND

Five general classes of sampling alternatives can be used to obtain groundwater samples from monitoring wells. These consist of:

- Manual collection procedures;
- Vacuum extraction procedures;
- Pneumatic or pressurized collection procedures;
- Mechanical collection procedures; and
- Gas entrainment methods.

Each of these broadly defined categories has numerous alternative strategies that can be used to collect the required sample volume. However, these vary more with respect to equipment selection or configuration, and less with respect to the basic principal used to pull or force the groundwater from the well into a collection reservoir. Since a complete review of all sampling strategies cannot be presented in this manual, a brief generalized description of the major categories is presented here for review. The intent of this introductory material is to highlight the advantages and/or disadvantages of each general class, thereby providing the reader with a basis for evaluating the options selected.

The information contained in this preliminary review is by no means complete, but it is hoped that it will be sufficient to allow the reader to judge or review the selected approach. Should additional detail be required, further review of the literature should be undertaken independently by the reader.

MANUAL COLLECTION PROCEDURES

Manual sampling techniques include all sampling procedures that involve extensive or repetitive manipulation of the identified equipment. As such, manual sampling alternatives encompass many procedures that could also be listed under the other general headings, but are not because they are implemented by hand. Generally, this category of sampling alternatives includes those simplest to implement on a one-time basis, but often the most difficult to use on a regular basis. Typically, sampling equipment and site preparation procedures are minimal, but frequently, equipment designs are crude and sample yields are small. Furthermore, usage may be labor-intensive, tedious, and time-consuming.

Examples of manual techniques that may be applied to groundwater sampling tasks include bailing with a device like a Kemmerer sampler, or hand pumping using either a suction or pressurized device. In operation, both of these options require only that the well site be accessible by foot, and that the collection device be adequate to draw the desired sample from the depth that it encounters.

The major disadvantage of hand-pumping operations is that only a limited pneumatic head or suction lift can be easily developed. Generally, suction lift is limited to 4.5 m (15 ft), and the pneumatic head is limited to roughly 4.2 kg/sq cm (60 lbs/sq in.). While devices can be obtained that have pressure or vacuum capacities in excess of these levels, their throughput per stroke is low, requiring that considerably more effort and time be expended to collect the required sample volume. For example, one hand-powered vacuum pump develops 70 cm (27.5 in.) of mercury vacuum but has only a 15-cc-per-stroke throughput.

A second approach that can be used to collect samples is bailing, using devices such as Kemmerer or Coliwassa samplers. One of the principal advantages of bailing is that there is no lift limitation. Through the use of extended lengths of cable or cord and winches or block and tackle, provisions can be made which will allow for the acquisition of samples from deep wells without too much effort. Shallow wells can also be readily accommodated by using a shorter cord length.

Baiiing does have disadvantages, however. Foremost among these is the significant amount of repetitive work required to prebail and then collect groundwater from a well. Not only is this effort tedious, but also it can be physically exhausting, depending on the weight of the sampler, cord, and sample and the availability of winches or block and tackle devices.

A second disadvantage of the bailing approach is that extra precautions must be taken to restrict the possibility of contamination. Not only is it essential that the bailer be thoroughly cleaned between well sites, but also it is imperative that provisions be made to protect the quality of the sample during its use at each well. The bailer should not be allowed to touch the surface of the ground during either the initial evacuation of a well or the collection cycles. If it does, it should be recleaned prior to reinsertion into the well.

Another problem that can arise during the use of a bailing method is that it is frequently difficult to completely evacuate a high-yielding well of standing water before it is replenished with fresh groundwater. This limitation may be offset through the use of ancillary equipment to prepare or prebail the well.

VACUUM EXTRACTION PROCEDURES

This sample collection alternative employs equipment that draws a vacuum within some collection device or tube, thereby causing the water to flow upward because of external pressure difference. Although some hand-held or hand-powered devices employ this technology, the emphasis of this discussion is placed on those devices which are driven by electric or gasoline motors or engines. As such, the equipment available for this approach is somewhat larger, heavier, and has a larger pumping capacity than does the manual equipment of the same nature.

In operation, devices such as peristaltic pumps or diaphragm pumps are used to evacuate some type of collection vessel. A suction tube of appropriate composition (non-reactive and non-contaminating) is lowered into the groundwater well, with the inlet point being positioned at or near the bottom. The vacuum source is then started, evacuating the sample line causing the water to be drawn to the surface. In cases where vacuum pumps are used, the water is drawn into a vessel where it is retained until it is transferred into an appropriate sample container. Alternatively, as is the case with a peristaltic pump, the water sample is drawn from the well through inert tubing, passed through the pump head, and then discharged under pressure to an appropriate collection device.

In theory, vacuum-type collection systems have several advantages, the principal one being that relatively inexpensive and compact devices exist that can rapidly complete the job of water collection. Another advantage of the vacuum-type approach is that, as necessary, provision can be made to flood the well casing with an inert atmosphere (such as nitrogen) without affecting one's ability to obtain a sample. This capability is particularly important in the situation of a low-yielding well, where the captured water cannot be turned over three to five times prior to sample withdrawal. In these cases, it probably is necessary to collect the sample from the available water that has stood within the well for periods of up to one month.

Since it is possible that standing water within a well is representative of existing groundwater chemistry because of oxidation which may have occurred, blanketing of the water with nitrogen may limit such a process, making the available groundwater more representative of what actually exists.

The principal disadvantage of a vacuum-system approach is that there is a limit of between 7.6 and 9.1 m (25-30 ft) on the length (above the groundwater surface) of the suction line. For depths in excess of this level, multiple-staged vacuum systems would have to be used to collect groundwater. Multiple-stage systems are not considered to be appropriate because they require the use of duplicate equipment and extensive site preparation.

A second disadvantage of the vacuum-type approach is that the fate of volatile species contained within the groundwater is unclear. Presumably, the process of pulling a vacuum on the water should cause a disturbance in the established equilibrium, driving some amount of volatile species (e.g., CO_2) out of the water and thus effecting chemical changes in the sample.

PNEUMATIC OR PRESSURIZED COLLECTION PROCEDURES

A third broad class of sampling alternatives that can be applied to groundwater sampling involves the use of pneumatic pressure to drive the desired water volume to the surface. This approach has two optional procedures, one involving the direct contact of the pneumatic fluid and the water and the other involving a pumping device. As has been discussed earlier, it is possible to use manually powered equipment to generate the pneumatic pressure, but these devices generally have limited utility because the pressures obtainable are limited to approximately 4.2 kg/sq cm (60 lbs/sq in.). However, when electric- or gasoline-powered engines or bottled gas are used to supply the pressure, it is quite easy to produce pressures of up to 7.0 to 17.6 kg/sq cm (100-250 lbs/sq in.). These pressure levels are adequate to permit the collection of groundwater from wells up to approximately 100 m (320 ft).

The simplest pneumatic system to visualize requires only that the well be capped and have two tubes feeding down into it. The first of these tubes is connected to the pressure source and is truncated immediately below the sealing cap. The second tube extends below the trapped groundwaters' surface and is used to conduct the sample to the surface. Ideally, as the well is pressurized, the groundwater would be forced upward only through the collection tube and into a collection receptacle. However, as the well itself is not completely leak-tight, groundwater is forced out through the screen and well bottom at varying rates depending on aquifer permeability. Not only may this restrict the amount of sample that can be conveniently collected with one pressurization step, but also it allows for the contamination of the surrounding groundwater with water that may have become stagnant within the well. Furthermore, if excessive pressure is pumped into the well casing and allowed to escape through the screen or the well's bottom, pockets of gas may become trapped within the aquifer which could alter aquifer yield characteristics or possibly even the groundwater chemistry.

Another disadvantage of having the pneumatic fluid come in contact with the isolated groundwater contained within the well is that such contact can cause changes within the dissolved oxygen content of the well water if air (which is the most common pneumatic fluid) is used.

Therefore, it is apparent that other arrangements of pneumatic equipment, in which the contact between the pneumatic fluid and the groundwater is minimized, are preferable. Such systems are commercially available in the form of piston and bladder pumps. The basic concept employed in either of these designs calls for the separation of the pneumatic flood chamber from the groundwater collection chamber. As the pneumatic chamber is pressurized, either the bladder expands or the piston is driven upward forcing trapped groundwater to move upward past a check valve and into a transfer tube. When the pressure is released, the bladder deflates or the piston moves downward, causing the collection chamber to refill. Groundwater contained within the transfer tube is prohibited from flowing back into the collection chamber because the check valve is closed.

As has been mentioned, the major advantage of this approach is that comparatively deep wells [100 m (328 ft)] can be sampled without much difficulty. The major disadvantage of this technique, however, is that the equipment used to complete the sampling is more expensive than alternative devices. Typically, piston or bladder pump systems cost between $400 and $1500, with compressors that develop 7.0 kg/sq cm (100 lbs/sq in.) costing up to an additional $300-$500. Although bottled gases can be used in place of the compressor, they have only a limited volume and must be replaced frequently.

MECHANICAL COLLECTION PROCEDURES

Another approach that can be used to obtain groundwater samples from a monitoring well includes the utilization of mechanical pumps that are located at the surface of or beneath the surface of the isolated water. Of all the approaches discussed to this point, this alternative appears to be the one that has the greatest flexibility with respect to speed of sample acquisition and preservation of sample integrity, but it also represents the one that is most difficult to implement under field conditions.

In operation, the pumping device is lowered down into the well and connected to the surface by means of an electrical cord and a sample recovery tube. When in place, the pump is switched on, drawing groundwater through the pump head and forcing it upward to the surface, where it may be collected within an appropriate receptacle. Since the pump (the body containing the motor and the head) may become partially wetted or immersed within the well water, the selected pump should be of an appropriate submersible or immersible design. Several such models are commercially available.

The major disadvantage of this sampling approach arises because most submersible pumps are 101 mm (4 in.) or larger in size. Since it is presumed at this time that most of the groundwater wells drilled will not be any larger than 50 mm (2 in.) or so in diameter, the use of this approach is precluded unless a smaller mechanical pump can be found.

GAS ENTRAINMENT METHODS

Gas entrainment or air-lifting is a fifth approach that can be used to collect groundwater samples from monitoring wells. Requiring similar equipment to that which is used in pneumatic systems, this technique represents little more than an alternative equipment configuration that can be used to force groundwater to a well's surface.

In operation, an air-lift system is comprised of two tubes and a source of pressurized air or other gaseous media. One of the tubes is used to conduct the pressurized gaseous media from grade level down to a point below the groundwater level. Upon release from the transport tube, the pressurized gas rises into the second tube, which is also positioned below the groundwater level. The mixing of the gaseous media with the groundwater causes a decrease in the unit weight of the trapped water allowing it to flow upward through the second tube. Because a void now exists within the second tube, groundwater flows into this tube and in turn is mixed with gas causing it to rise. By regulating the flow of compressed gas, it becomes possible to drive the groundwater all the way to the well's surface where it can be collected.

The application of gas entrainment techniques to groundwater sampling exercises has several disadvantages. One obvious disadvantage is that large volumes of compressed gases are usually required to drive the groundwater to the well's surface. This implies that either high-capacity compressors or numerous gas cylinders may be required to complete individual sampling operations. As such, field transport of the necessary equipment becomes more troublesome, and may prove to be impossible in any situation where a monitoring well is remotely situated.

Another disadvantage of the gas entrainment technique, however, lies in the fact that the chemical, physical, or biological integrity of the sample is very likely to be lost. Several avenues of sample degradation exist. First, because of the unit density reduction, volatile species (such as dissolved oxygen) and carbon dioxide trapped within the groundwater may be liberated, thereby changing the chemistry of the sample, and may produce, in some cases, precipitation of trace elements. Alternatively, contaminants present within the lift gas may replace volatile species contained within the well water, thereby altering the chemistry of the sample.

EXHIBIT A.7-1

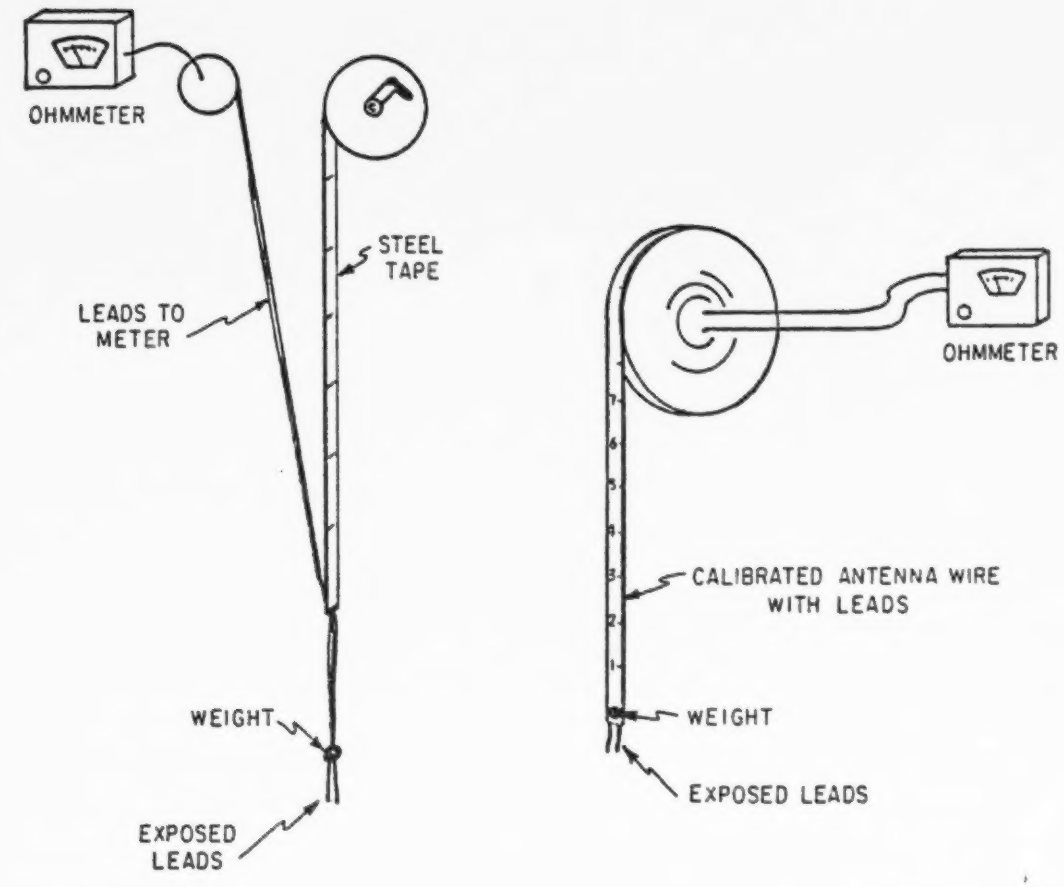
PROCEDURE FOR MEASUREMENT OF GROUNDWATER LEVEL

The following steps describe the procedure for measuring groundwater level with devices such as those shown in Figure 1.

1. Remove the locking protective cover at the well to be monitored.
2. Attach the cable to the ohmmeter and turn on the unit. An open circuit (zero reading) should be observed. The exposed ends of the cable should be wiped dry before insertion into the well riser pipe.
3. Insert the cable until the ohmmeter registers a closed circuit. Several readings should be obtained for consistency and repeatability.
4. Mark the cable at the point which coincides with an established survey elevation mark on the protective casing. It is often desirable to check each reading to be sure that the circuit is closed by true water surface rather than water on the side of the wire or pipe. A sharp tug should shake water off the cable.
5. If permanent pressure gauges are installed on the user pipe (artesian wells), bleed off any air bubbles within the system through the needle valve and record the stabilized pressure gauges reading in psi.

The following items should be recorded on the appropriate data sheets (metric and English units):

Identification:	Plant name, state, piezometer number, location tip, elevation.
Observations:	Date and exact time, elevation of top of riser pipe, water level (elevation), gauge pressure (if applicable), temperature (from SCT meter), weather, any unusual activities in progress in area of well.


OHMMETER
STEEL TAPE
LEADS TO METER
WEIGHT
EXPOSED LEADS
OHMMETER
7
6
5
4
3
2
1
CALIBRATED ANTENNA WIRE WITH LEADS
WEIGHT
EXPOSED LEADS

Source: Arthur D. Little, Inc.

FIGURE 1 GROUNDWATER LEVEL MEASUREMENT DEVICES

EXHIBIT A.8-1

CLEANING OF EQUIPMENT

The following procedure is recommended for cleaning sampling and analysis equipment*:

1. Wash with hot detergent.
2. Rinse at least three times with tap water.
3. Rinse all sample containers and analytical glassware with 1:1 HNO_3:H_2O.
4. Rinse at least three times with tap water.
5. Rinse at least three times with distilled water.
6. ** Rinse one time with high-purity water (MilliQ^R).
7. Dry in air.

---

* Quantities are not specified but sufficient volume should be used to thoroughly soak and/or rinse both internal and external surfaces.

** For those containers to be used to obtain samples for organic analysis, a final rinse using acetone will be made.

EXHIBIT A.11-1

CHAIN-OF-CUSTODY PROCEDURES

To implement the chain-of-custody procedures in the field, the following steps must be taken:

1. At the time of sample collection, all sample labels must be filled out completely and clearly. In addition to filling out all appropriate sample identifiers, each label must be signed or initialed by the collector.
2. When a sample is collected, an entry of that fact should be made within the field observation notebook. This page and all others should be signed and dated.
3. The cap of any sampling container should be sealed with tape. Any attempt to open the container subsequent to the application of sealing tape should irreparably damage the tape.*
4. Entries into the packing log book should be clear and concise. At the completion of the packing exercise, the shipping list should be signed and dated. The tear-out page should be removed and attached to the shipping container to serve as the packing list.
5. When full, the shipping container should be sealed with tape. Any attempt to open the package should cause irreparable damage to the tape.
6. Upon shipment, a copy of the bill of lading should be obtained from the carrier. This bill should be signed by a representative of the carrier and be dated. This bill of lading should be retained by the sampling crew chief until such time as he can personally turn it over to the sample custodian in the laboratory.
7. Upon receipt of the samples in the lab, the custodian should receive a second copy of the bill of lading. As before, this should be signed and dated.
8. The custodian should inspect the shipping container to see if any obvious signs of tampering have occurred. If signs are noted, this should be entered in the

laboratory log book.

9. The package may then be opened and each sample container then inspected individually. If tampering is noted, an indication of this should be entered in the notebook.

10. Using the packing list provided, the custodian should log in all samples. This should be cross-checked by actual bottle inspection.

11. The custodian then attaches and signs a chain-of-custody tag to each sample container. The containers are then secured in a lock-safe location.

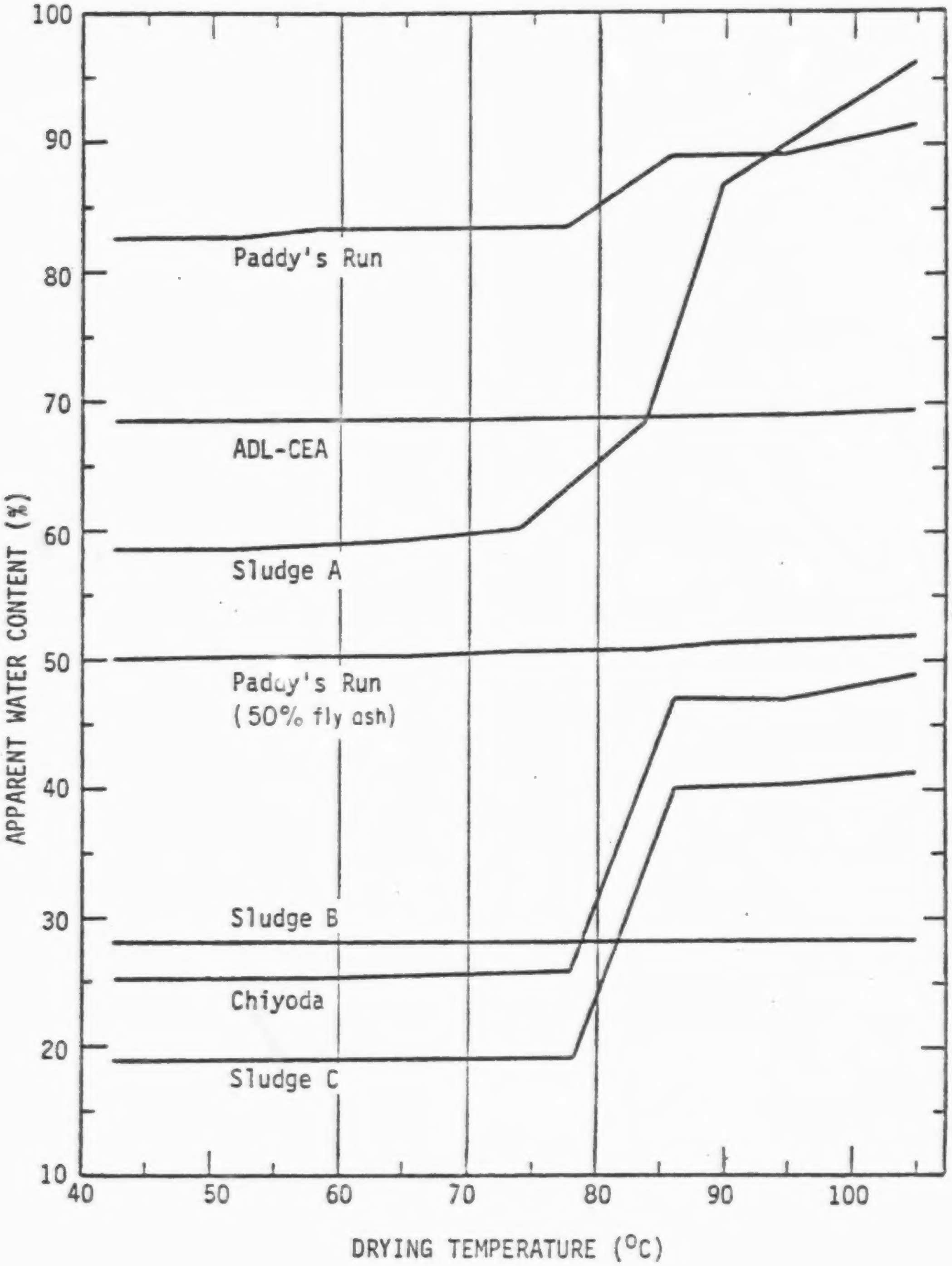
12. As the samples are distributed, each person handling the samples should sign and date the chain-of-custody tag. The date tag should list all days that the sample was under their control. As additional tags are needed, they should be added. Old tags should be returned to the custodian for his records.

13. When all analyses are complete the final disposition of any remaining sample (i.e., disposal or archival storage) should be entered into the laboratory log book.

- Any wells installed under this program will be locked and sealed with tape as described. Existing utility wells which may also be sampled in this program will also be sealed; however, the utility will maintain access to these wells.

EXHIBIT B.2-1

EFFECT OF DRYING TEMPERATURE ON WATER-CONTENT DETERMINATION OF FGC WASTES



Source: Reference 5.5.

FIGURE 1 EFFECT OF DRYING TEMPERATURE ON WATER-CONTENT DETERMINATION OF FGC WASTES

EXHIBIT B.3-1

PROCEDURE FOR PRESSING LIQUOR FROM FGC AND SOIL SAMPLES

Figure 1 shows a schematic of the pressing apparatus. The following is a procedure for using this apparatus to obtain water samples for analysis from wet solid (FGC or soil) materials.

1. Tighten the steel jacket onto the base plate with the wingnuts. Place the stainless steel (325-mesh) screen into the jacket and hold it flat with a rod while filling the container with sample. Guidance as to the volume (or weight) of sample to be used is given in Table 1. A layer of 1 in. in the apparatus roughly corresponds to 200 mL volume of solid.
2. Place the plunger inside the jacket and push until it is firmly held by the sides. Place the apparatus into the hydraulic press. Place a thick plate on top of the plunger to avoid deformation by the ram of the press. Place a graduate of appropriate size at the liquid outlet.
3. Apply 20 tons of pressure on the plunger for an appropriate period of time, either until a required volume of liquid is obtained or until it is determined that this method will not wash. The pressure may need readjustment from time to time. The liquid is then filtered through 0.45 um filter and preserved as needed for subsequent analysis.

In special cases where exposure to air may cause major chemical changes, the whole apparatus may have to be maintained under a nitrogen atmosphere. In this case, it may be necessary to load the apparatus in a nitrogen bag and to protect it and the liquor squeezed out from oxygen during this squeezing process.

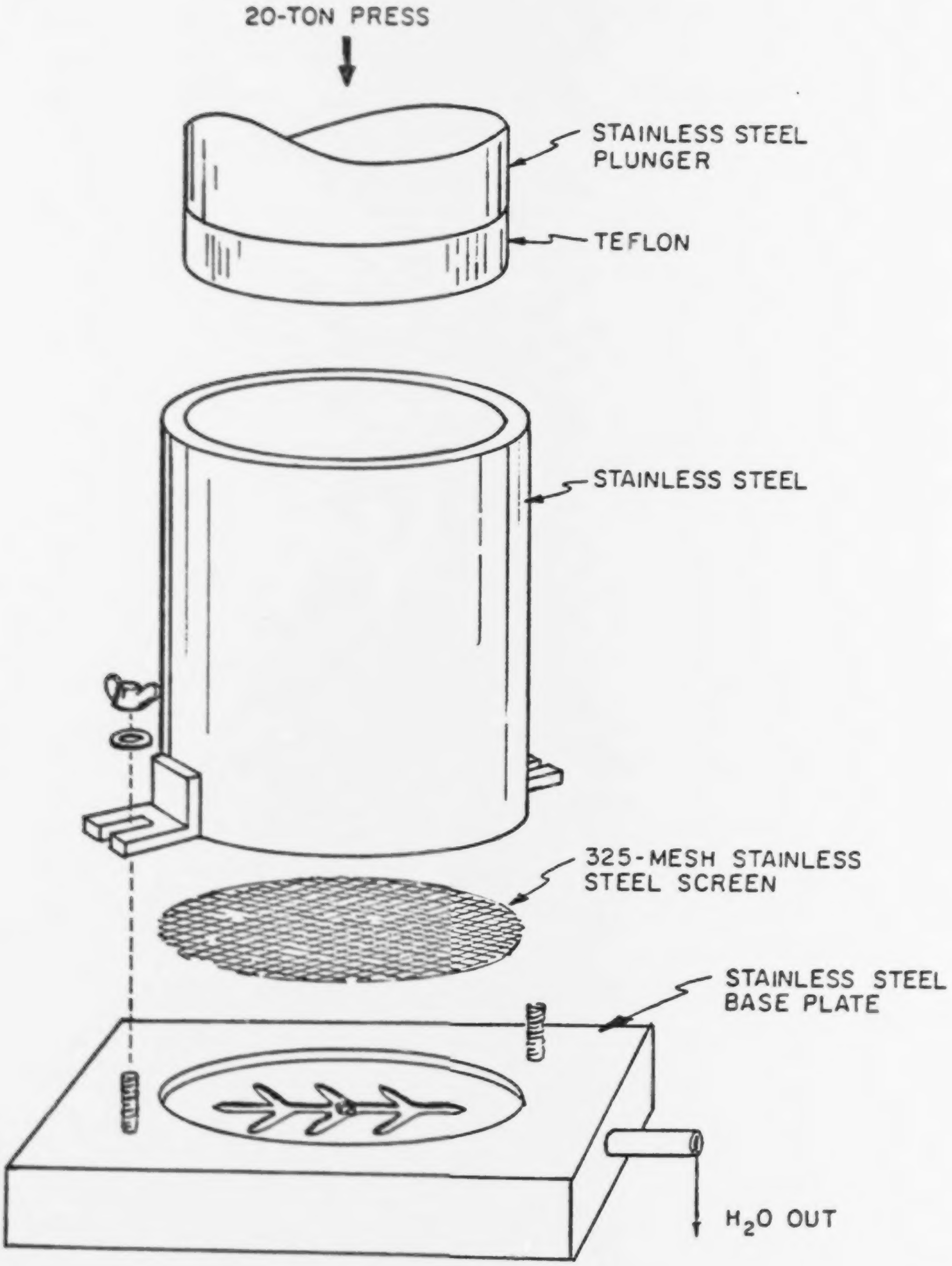
TABLE 1

EXAMPLE DATA FOR SQUEEZING VARIOUS SAMPLES

Sample	Weight (g)	Initial % Moisture	Final % Moisture	Volume H_2O Obtained (mL)	Time Squeezed[1] (hrs)
Soil	196	~26	~15	27	2
Soil	590	~26	~15	85	2
Forced Oxidation FGD Waste	303	~20	~19	7	2
Forced Oxidation FGD Waste	303	~20	~19	10	18
Dual Alkali Waste	236	~42	~24	58	2
Dual Alkali Waste	236	~42	~23	60	6
Fly Ash	133	~30	~23	9	2

1. Initial load of 20 tons.

Source: Arthur D. Little, Inc.


20-TON PRESS
STAINLESS STEEL PLUNGER
TEFLON
STAINLESS STEEL
325-MESH STAINLESS STEEL SCREEN
STAINLESS STEEL BASE PLATE
H_2O OUT

Source: Arthur D. Little, Inc.

FIGURE 1 SCHEMATIC OF PRESSING APPARATUS

EXHIBIT B.4-1

DIGESTION AND FUSION PROCEDURES

SUMMARY OF DIGESTION PROCEDURES FOR LIQUID SAMPLES

1. For analysis of liquid samples by ICAP, no predigestion is needed.
2. For analysis of liquids for mercury by cold vapor, a HNO_3/H_2SO_4 reflux followed by dichromate addition is needed.
3. For analysis of liquids for arsenic and selenium by hydride evolution and all other metals by graphite furnace AA, the following procedure is given. Transfer 100 mL of sample into a 250-mL Griffin beaker and add 3 mL of concentrated redistilled HNO_3 and 5 mL of 30% H_2O_2. Heat for one hour at 95°C or until volume is slightly less than 50 mL. Cool and bring to 50-mL volume with de-ionized water (Ref. 5.9).
4. For analysis of liquid samples for metals using flame AA, the following procedure is given. Transfer an appropriate volume of well-mixed sample into a Griffin beaker and add 3 mL of concentrated redistilled HNO_3. Place beaker on a hot plate and evaporate to dryness, making certain the sample does not boil. Cool and add another 3 mL of concentrated redistilled HNO_3. Reflux and keep adding acid until digestion is complete (indicated by a light-colored residue). Add sufficient dilute HCl (1 volume concentrated HCl to 1 volume de-ionized water); warm to dissolve residue. Transfer to a volumetric container and dilute to the appropriate volume with water. Let any insoluble residue settle (SiO_2) and aspirate the supernate into the atomizer.

SUMMARY OF DIGESTION PROCEDURES FOR SOLIDS

1. Reverse HF, Total Acid Attack (for high organic soil and FGC samples, ICAP analysis).*

   a) Add a 500-mg sample to a 60-mL, Teflon beaker.
   b) Add 4 mL of concentrated $HClO_4$ and 16 mL concentrated HNO_3.
   c) Heat in a sand bath to reflux.
   d) If pale yellow (indicates little organic remains) carry to $HClO_4$** fumes. If brown, repeat adding concentrated HNO_3 until pale yellow, then carry to $HClO_4$ fumes.
   e) Add 1 mL of HNO_3 and 15 mL of concentrated HF.**
   f) Heat to dryness in a sand bath at 100°C.
   g) Add 2 mL concentrated HCl.
   h) Add contents to a 50-mL volumetric, make up with 0.5 M HCl; warm to dissolve insoluble material.

2. Normal HF Digestion (for low-organic FGC waste and soil samples)*

   a) Add a 500-mg sample to a 60-mL Teflon beaker.
   b) Add 15 mL concentrated HF,** 4 mL $HClO_4$,** 1-2 mL HNO_3.
   c) Heat in a sand bath at 100°C.
   d) Carry to the digestion dryness.
   e) Add 2 mL concentrated HCl and make to volume (50 mL) with 0.5 N HCl. Heat to dissolve insoluble residue.

* This digestion procedure will be performed by Barringer Magenta Ltd., Toronto, Canada. One half or more of this digest will be sent to the laboratory sending the sample (Arthur D. Little, Inc. or TRW) for QC or other required AA analyses.

** Extreme caution must be exercised when working with perchloric and hydrofluoric acids because $HClO_4$ can form explosive by-products when contacted with certain organics and HF can cause extensive skin, tissue and bone damage if contacted with the skin.

SUMMARY OF DIGESTION PROCEDURES FOR SOLIDS

1. Reverse HF, Total Acid Attack (for high organic soil and FGC samples, ICAP analysis).*

   a) Add a 500-mg sample to a 60-mL, Teflon beaker.
   b) Add 4 mL of concentrated $HClO_4$ and 16 mL concentrated HNO_3.
   c) Heat in a sand bath to reflux.
   d) If pale yellow (indicates little organic remains) carry to $HClO_4$** fumes. If brown, repeat adding concentrated HNO_3 until pale yellow, then carry to $HClO_4$ fumes.
   e) Add 1 mL of HNO_3 and 15 mL of concentrated HF.**
   f) Heat to dryness in a sand bath at 100°C.
   g) Add 2 mL concentrated HCl.
   h) Add contents to a 50-mL volumetric, make up with 0.5 M HCl; warm to dissolve insoluble material.

2. Normal HF Digestion (for low-organic FGC waste and soil samples)*

   a) Add a 500-mg sample to a 60-mL Teflon beaker.
   b) Add 15 mL concentrated HF,** 4 mL $HClO_4$,** 1-2 mL HNO_3.
   c) Heat in a sand bath at 100°C.
   d) Carry to the digestion dryness.
   e) Add 2 mL concentrated HCl and make to volume (50 mL) with 0.5 N HCl. Heat to dissolve insoluble residue.

* This digestion procedure will be performed by Barringer Magenta Ltd., Toronto, Canada. One half or more of this digest will be sent to the laboratory sending the sample (Arthur D. Little, Inc. or TRW) for QC or other required AA analyses.

** Extreme caution must be exercised when working with perchloric and hydrofluoric acids because $HClO_4$ can form explosive by-products when contacted with certain organics and HF can cause extensive skin, tissue and bone damage if contacted with the skin.

3. Digestion for Hg Analysis (by cold vapor)* (See Figure 1 for apparatus).

a) Place sample (5 g or less) into 250-mL round-bottom flask and wash down with distilled water.

b) Add 10 mL of nitric acid and attach condenser with Raschig rings; turn on cold water to condenser.

c) Add 20 mL of H_2SO_4 slowly through the top of the condenser; wash down with 10% HNO_3. Maintain temperature of 120°C with heating mantel until all frothing due to reaction with organic materials has subsided.

d) Cool, and add 10 mL perchloric acid and 10 mL of nitric acid. Remove water from condenser jacket. Increase temperature to 160°C and then raise in slow increments until H_2SO_4 fumes appear.

e) Cool, and wash down condenser with water (not HNO_3). After condenser is cooled by water, wash with 10% HNO_3.

f) Carefully smell the solution. If a strong Cl_2 smell is present, continue digestion until all Cl_2 has been expelled.

g) Add a small amount of HF to dissolve silica film inside flask; warm 1 hour to dissolve.

h) Add sufficient dichromate to make solution 0.01% in $Cr_2O_7^{=}$ when diluted to final volume.

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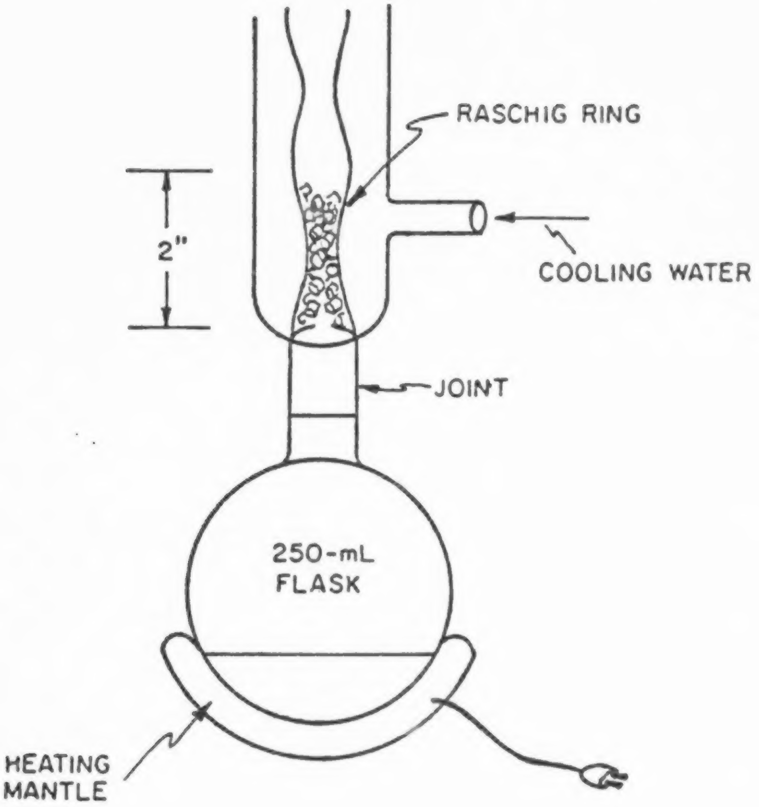
* M.S. Epstein, et al., "Analysis of Mercury in Standard Reference Materials by Cold-Vapor Atomic Absorption," FACSS Second National Meeting Indianapolis, Indiana, Oct. 6-10, 1975.


RASCHIG RING
2"
COOLING WATER
JOINT
250-mL FLASK
HEATING MANTLE

Source: Arthur D. Little, Inc.

FIGURE 1 MERCURY DIGESTION APPARATUS

4. Digestion of Solids for As and Se Determination by Hydride Evolution

This procedure is similar to the one used for Hg (part 3) except for the following modifications:

a) Use HCl instead of HNO_3 throughout.

b) Add 5 mL H_2SO_4, 5 mL $HClO_4$, and 5 mL HCl in the first step (to 0.5-g sample).

c) Use only air condenser, no water.

d) Take mixture to fumes of H_2SO_4.

e) Wash condenser with 20% HCl.

f) The final solution should be 20% in HCl and 5% in H_2SO_4 and minimum of HF to dissolve silica. Heat in Teflon beaker.

g) Add nitric acid as needed as part of analysis procedure.

5. Fusion with Na_2CO_3, $Ca(OH)_2$ (for B or Si analysis)

(a) Weigh an approximately 0.1-g sample into a platinum crucible. Fuse with 1 g of Na_2CO_3. Then add sufficient 1 N HCl to dissolve the melt and dilute to 100 mL.

(b) Alternatively, fuse 1 g with 0.1 g of Ca $(OH)_2$ at 500°C for 1 hour. Dissolve in 1 N HCl.*

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*Higgins D.J., J. Sci. Food. Agr. 2 (1951) 498.

EXHIBIT C.2-1

DESCRIPTION FOR CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST WITH PORE PRESSURE MEASUREMENTS*

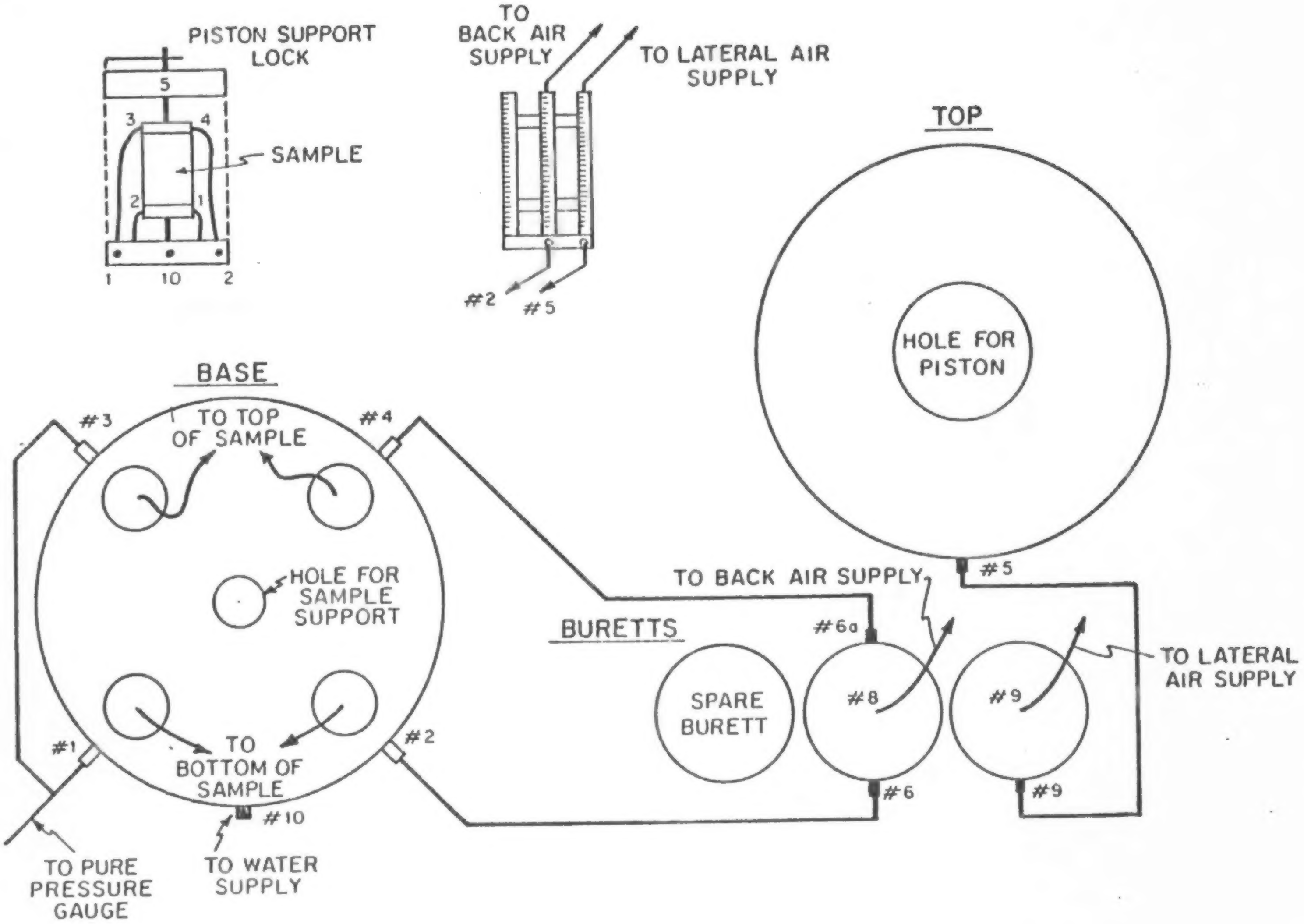
Procedures for the consolidated-undrained triaxial compression test with pore pressure measurements will be divided into sample preparation, chamber preparation, line saturation, consolidation, shearing, and end-of-test phases. A complete test will include a minimum of three samples consolidated to the desired pressure and loaded to failure. Results of the tests will be plotted on stress-path tangency curves. If necessary, additional points will be added to prepare a straight line failure plot of the waste material.

Sample preparation involves extruding the sample from the Shelby tube, trimming the sample, and placing the membranes over the heads and the sample. A sample will be extruded from the Shelby tube and trimmed to a height of approximately 15 cm (5.9 in.). After weighing, the sample will be placed on the bottom head of the trimmed chamber pedestal, the top head will be set on the sample, and a membrane will be placed over the entire arrangement. Two rubber "O"-rings each will be placed around the membranes at the top head and at the bottom head.

Once the membranes are attached, the remaining chamber apparatus will be assembled as shown on Figure 1. The chamber will then be filled with water and all the air will be flushed and replaced with water.

Samples will be consolidated in the chamber by applying a specified chamber pressure and recording the volume change of the sample through the line connected to the bottom head. Volume change-time data will be taken to determine when primary consolidation is completed and also to calculate compression data for the sample. A Casagrande construction on a volume change-log time scale will be applied to calculate when loading of the sample can begin.

Sample saturation will be determined by increasing the cell pressure by 10 psi and measuring the instantaneous pore pressure


PISTON SUPPORT LOCK
5
3
4
SAMPLE
2
1
1
10
2
TO BACK AIR SUPPLY
TO LATERAL AIR SUPPLY
#2
#5
TOP
HOLE FOR PISTON
BASE
#3
TO TOP OF SAMPLE
#4
HOLE FOR SAMPLE SUPPORT
#1
TO BOTTOM OF SAMPLE
#2
#10
TO PURE PRESSURE GAUGE
TO WATER SUPPLY
TO BACK AIR SUPPLY
#5
BURETTS
#6a
SPARE BURETT
#8
#9
TO LATERAL AIR SUPPLY
#6
#9

Source: Bowser-Morner Testing Laboratories, Inc.

FIGURE 1 CHAMBER APPARATUS ASSEMBLY

reading. If the pore pressure is also 10 psi, the sample is fully saturated. If not, an equal back pressure will be applied before further consolidation can occur. This sequence of steps will be repeated until all air is forced into saturation.

Once the sample has been properly consolidated and saturated, shearing will begin in strain-controlled compression machines. Shearing will proceed at a constant rate of deformation and readings of load, pore pressure, and deformation will be recorded. Because of the permeability of the wastes to be tested, a deformation rate of 0.01 in./min will be used to allow proper equalization of pore pressure.

EXHIBIT C.2-2

DESCRIPTION FOR EXTENDED PERMEABILITY ANALYSES

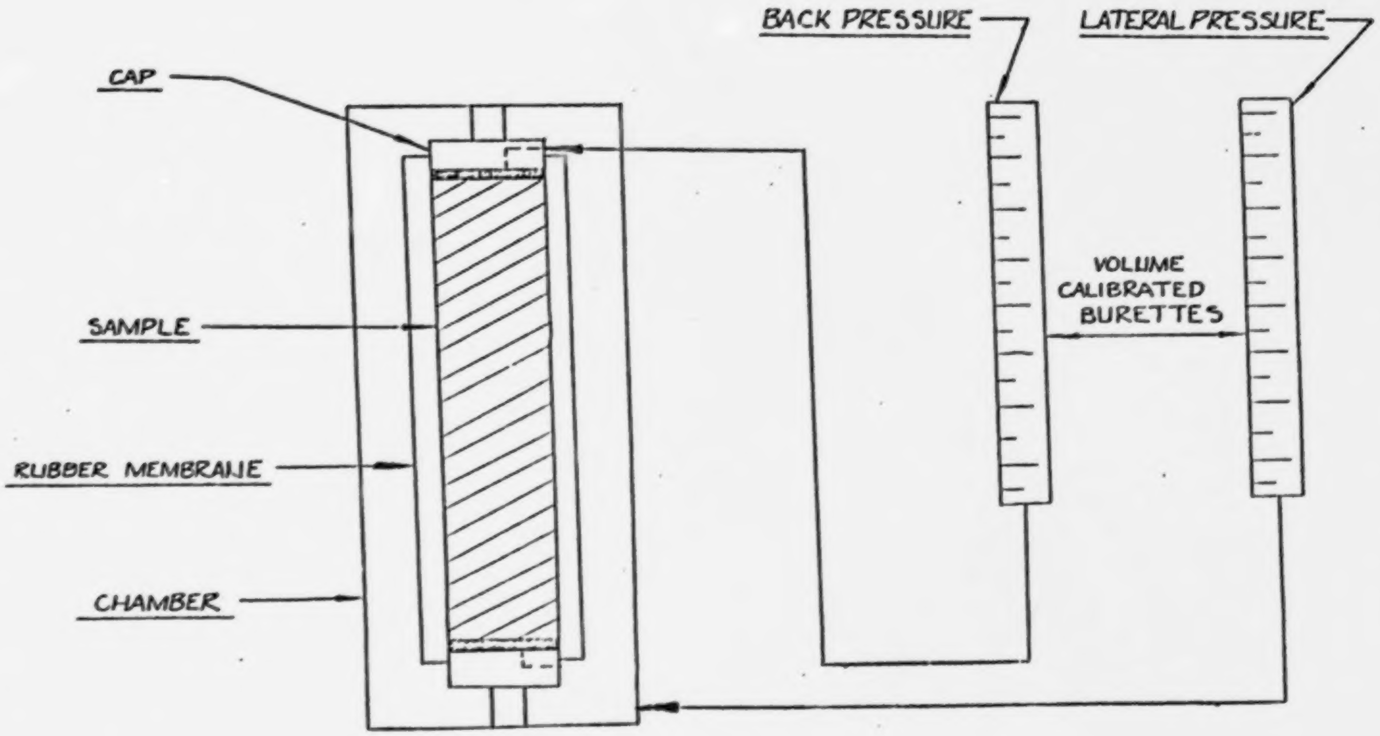
Permeability analyses will be performed in accordance with ASTM procedures and guidelines presented in "Soil Testing for Engineers" by T.W. Lambe* as previously documented. Triaxial chambers will be adapted for the permeability and extended permeability testing. Undisturbed samples recovered from the site development will be prepared and installed in the chambers as shown in Figure 1. Back pressure saturation will then be performed as described in the procedure outlined in Exhibit C.2-1 for "Consolidated-Undrained Triaxial Compression Tests with Pore Pressure Measurements."* Once this procedure has been accomplished, water will be allowed to pass from a pressurized high through the sample out to atmospheric pressure. The back pressure will remain constant as water passes through the sample and the water intake will be monitored using a calibrated burette. During the permeability tests, lateral pressures will exceed back pressure by no more than 2.5 psi to avoid any excess consolidation. Several pressures will be utilized over several days to ensure consistent determinations of the coefficient of permeability.

An extended permeability analysis will be made using the same basic procedure. However, in extended permeability tests the previously described permeability tests will be performed and then incremental increases in lateral pressure will be applied to consolidate the sample to higher densities. The change in volume will be monitored by observation of the water level in a calibrated burette to determine when primary consolidation has finished. The initial dry density and moisture content can be calculated as described by Lambe. Further dry density calculations can be made as follows.

$$\text{Final dry density} = \frac{(\text{initial volume})\,(\text{initial dry density})}{(\text{initial volume} - \text{change in volume})}$$

The coefficient of permeability during each stage of the permeability test is calculated based on Darcy's law as follows:

$$k = \frac{Q\,L\,C}{t\,h\,D^2}$$


CAP
SAMPLE
RUBBER MEMBRANE
CHAMBER
BACK PRESSURE
LATERAL PRESSURE
VOLUME
CALIBRATED
BURETTES

Source: Arthur D. Little, Inc.

FIGURE 1 SCHEMATIC DRAWING OF SATURATION PHASE

where

Q = quantity of water flow in cc;

L = height of samples in in.;

t = time in sec;

h = back pressure in psi;

D = diameter of samples in in.;

C = conversion factor, 7.13×10^{-3}; and

k = permeability in cm/sec.

A plot of dry density versus coefficient of permeability (semi-log) can then be developed for one sample.

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* Soil Testing for Engineers, T.W. Lambe, John Wiley & Sons, Inc., New York, 1951, pp. 52-62.

EXHIBIT D.3-1

ATOMIC ABSORPTION SPECTROPHOTOMETRIC DETERMINATION OF ARSENIC BY HYDRIDE GENERATION

SUMMARY OF METHOD

An aqueous solution of sodium iodide is added to an aliquot of the acidified sample to reduce As(V) to As(III). AS(III) is converted to arsine, AsH_3, by addition of an aqueous solution of sodium borohydride. The AsH_3 thus formed is immediately transferred by argon carrier gas flowing through the reaction vessel into the atomizer of an atomic absorption spectrophotometer. The AsH_3 is burned in an argon-hydrogen flame, and the absorption signal at 193.7 nm is recorded.

APPARATUS

Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer, equipped with 3-slot 10-cm burner or equivalent

Perkin-Elmer Arsenic Electrodeless Discharge Lamp or equivalent

Strip-chart recorder

Hydride generation apparatus:

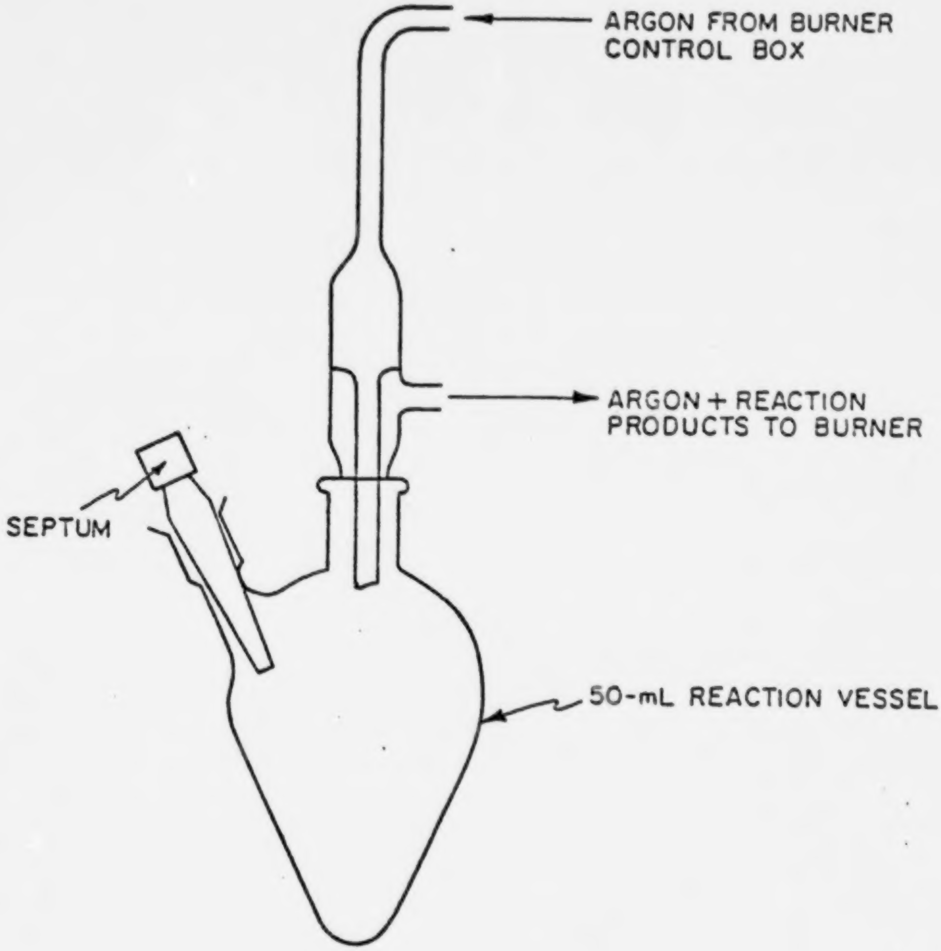
Gas inlet-outlet tube; Ace Glass 9513-04 gas burning apparatus, inner portion only with glass frit removed, 14/20

Reaction flask; Ace Glass 9481-08 pear-shaped microflask

Syringe; Becton-Dickinson 3-cc PLASTIPAK disposable syringe needles (SGA Scientific S-9950), 22-gauge.

PIPETMAN 2-200 microliter adjustable autopipet; Rainin Instrument Company, P200D.

The hydride generation apparatus and transfer system are shown in Figure 1. The reaction flask is supported by a ringstand. Tygon tubing is used for all connections. Hydrogen is introduced through the fuel ("acetylene") port, argon through the oxidant ("air atom") port, and AsH_3 through the auxiliary oxidant


ARGON FROM BURNER CONTROL BOX
ARGON + REACTION PRODUCTS TO BURNER
SEPTUM
50-mL REACTION VESSEL

Source: Arthur D. Little, Inc.

FIGURE 1 HYDRIDE GENERATION APPARATUS AND TRANSFER SYSTEM

("air aux") port on the burner head. Argon flow rates of 18.5 L/min to the atomizer and 5 L/min through the reaction vessel are obtained by appropriate adjustments of the aspirator and the auxiliary oxidant flow control valve on the burner control box.

REAGENTS AND GASES

Hydrochloric acid, concentrated, reagent grade.

Sodium hydroxide, electrolytic pellets.

Sodium borohydride solution. Dissolve 4 g $NaBH_4$ (Alfa Products 14122 10/32" pellets) in 100 mL of a 10% (w/v) NaOH solution.

Sodium iodide solution. Dissolve 10 g NaI (reagent grade) in 100 mL distilled water.

Arsenic stock solution. Prepare a 1-ppm arsenic stock solution by serial dilution of 1000-ppm reference standard (Fisher-Certified Arsenic 1000-ppm Atomic Absorption Standard).

Argon gas, commercial grade (99.9%).

Hydrogen gas, commercial grade (99.95%).

PROCEDURE

Pipet 10 mL of sample into a reaction flask. Add 10 mL concentrated HCl. Add 0.5 mL NaI pre-reductant and allow a minimum of one minute for the reaction to occur. Prepare standards, including a reagent blank, from the 1-ppm arsenic stock solution by appropriate microliter additions to 10 mL of distilled water in the reaction flasks and treat similarly.

Attach the reaction flask to the transfer system. Allow at least 10 seconds for the argon to flush out the system and then inject rapidly, but with uniform pressure, 2.5 mL sodium borohydride solution into the reaction vessel using a syringe and 22-gauge needles. Record the absorption signal. Repeat for each standard and sample. Determine concentrations from peak heights.

APPLICATION

This method may be used to analyze solutions containing as little as 0.5 ug/L As (amount of element which produces 1% absorption).

Representative calibration data are shown in Table 1. The relative standard deviations of measured absorbance range from 0.9 to 4.1% over the 0.05 ug As range. Typical absorption signals for samples containing 0.3 ug As in 4 M HCl are shown in Figure 2.

INTERFERENCES

No significant effect on the arsenic absorbance is observed in the presence of 1000-fold excesses of Mn, Pb, Cu, Fe, Sb, and Se in 4 M HCl.

The sensitivity obtained by analyzing standards containing 3 mL HCl and 1.5 mL HNO_3 (0.83 abs/ug As) was found to be only slightly less than the sensitivity in 4 M HCl (0.89 abs/ug As over the same range).

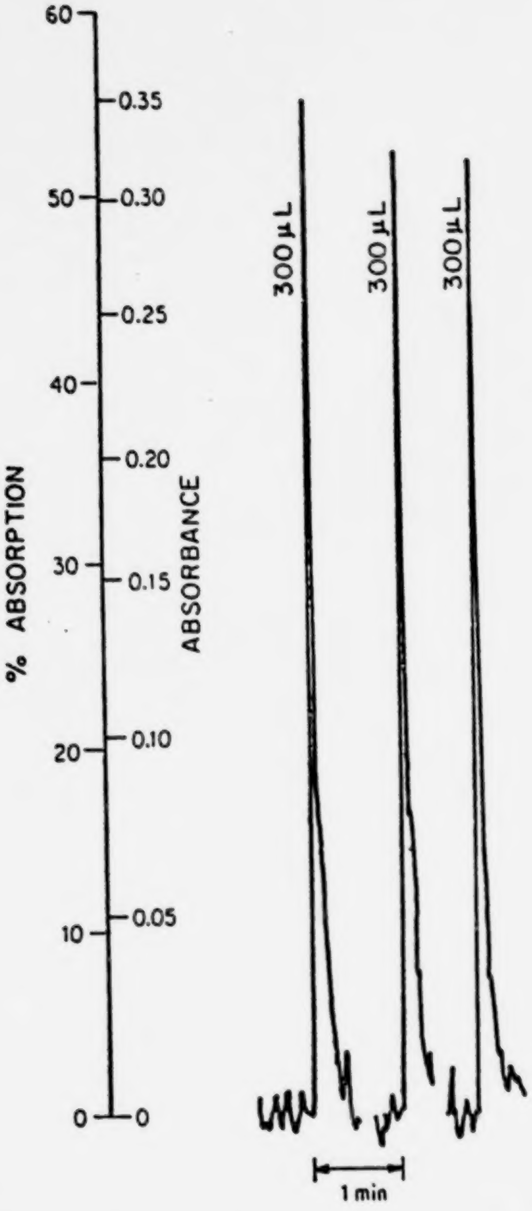
TABLE 1

CALIBRATION DATA FOR ARSENIC IN 4M HCl[1,2]

Arsenic Added (μg)	Absorbance	Mean	Standard Deviation	Relative Standard Deviation (%)
Blank	.087, .097, .096	.093	.006	–
.05	.135, .140, .135	.137	.003	2.2
.10	.200, .184, .195	.193	.008	4.1
.15	.230, .226, .228	.228	.002	0.9
.20	.265, .277, .275	.272	.006	2.2
.25	.318, .321, .333	.324	.008	2.5
.30	.345, .348, .353	.349	.004	1.1

1. All samples contain 10 mL H_2O, 5 mL conc. HCl.
2. 0.5 mL 10% NaI added to all samples; 1 minute allowed for reaction before addition of $NaBH_4$.

Source: Arthur D. Little, Inc.



Source: Arthur D. Little, Inc.

FIGURE 2 TYPICAL ABSORPTION SIGNALS FOR SAMPLES CONTAINING 0.30 µg ARSENIC IN 4 M HCl

EXHIBIT D.3-2

ATOMIC ABSORPTION SPECTROPHOTOMETRIC DETERMINATION OF SELENIUM BY HYDRIDE GENERATION

SUMMARY OF METHOD

Se(IV) is converted to selenium hydride, SeH_2, by addition of an aqueous solution of sodium borohydride. The SeH_2 thus formed is immediately transferred by argon carrier gas flowing through the reaction vessel into the atomizer of an atomic absorption spectrophotometer. The SeH_2 is burned in an argon-hydrogen flame and the absorption signal at 196.1 nm is recorded.

APPARATUS

Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer, equipped with 3-slot 10-cm burner (or equivalent)

Perkin-Elmer Arsenic Electrodeless Discharge Lamp (or equivalent)

Strip-chart recorder

Hydride generation apparatus:

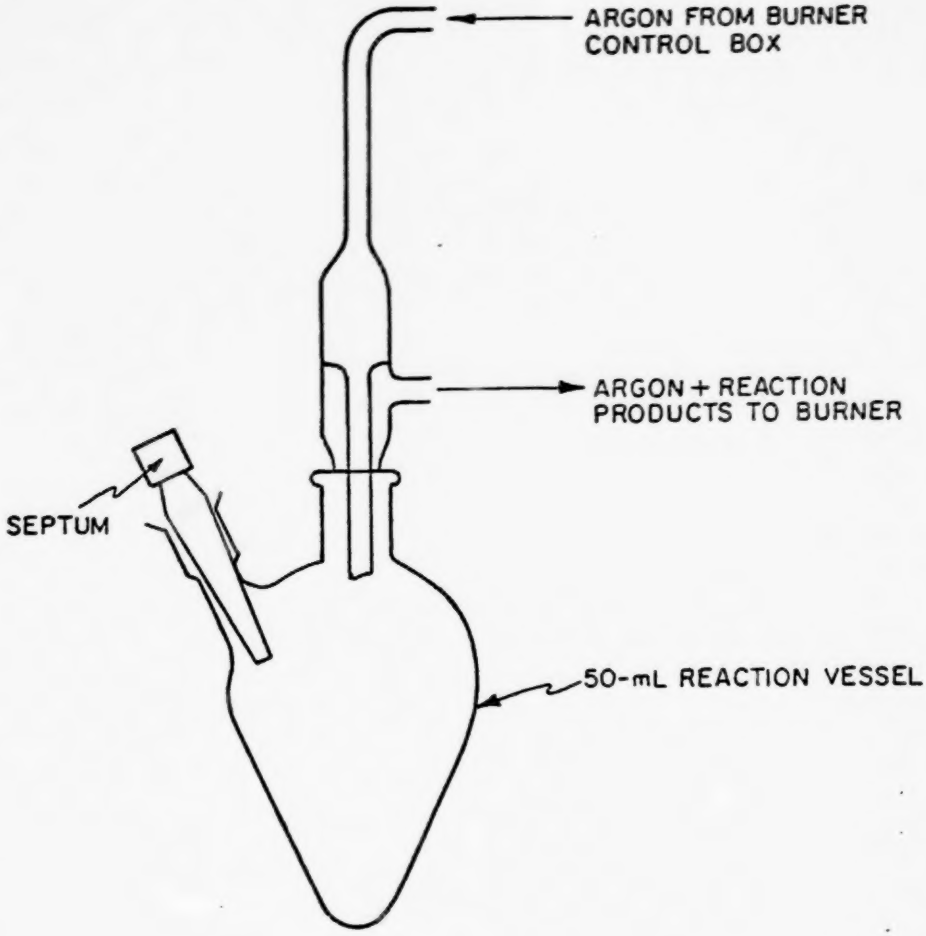
Gas inlet-outlet tube; Ace Glass 9513-04 gas burning apparatus, inner portion only with glass frit removed, 14/20

Reaction flask; Ace Glass 9481-08 pear-shaped microflask

Syringe; Becton-Dickinson 3-cc PLASTIPAK disposable syringe needles (SGA Scientific S-9950), 22-gauge (or equivalent).

PIPETMAN 2-200 microliter adjustable autopipet; Rainin Instrument Company, P200D.

The hydride generation apparatus and transfer system are shown in Figure 1. The reaction flask is supported by a ringstand. Tygon tubing is used for all connections. Hydrogen is introduced through the fuel ("acetylene") port, argon through the oxidant ("air atom") port, and AsH_3 through the auxiliary oxidant ("air aux") port on the burner head. Argon flow rates of 18.5 L/min to the atomizer and 5 L/min through the reaction vessel are


ARGON FROM BURNER CONTROL BOX
ARGON + REACTION PRODUCTS TO BURNER
SEPTUM
50-mL REACTION VESSEL

Source: Arthur D. Little, Inc.

FIGURE 1 HYDRIDE GENERATION APPARATUS AND TRANSFER SYSTEM

obtained by appropriate adjustments of the aspirator and the auxiliary oxidant flow control valve on the burner control box.

REAGENTS AND GASES

Hydrochloric acid, concentrated, reagent grade.

Sodium hydroxide, electrolytic pellets.

Sodium borohydride solution. Dissolve 4 g $NaBH_4$ (Alfa Products 14122 10/32" pellets) in 100 mL of a 10% (w/v) NaOH solution.

Selenium stock solution. Prepare a 1-ppm selenium stock solution by serial dilution of 1000-ppm reference standard (Fisher-Certified Arsenic 1000-ppm Atomic Absorption Standard).

Argon gas, commercial grade (99.9%).

Hydrogen gas, commercial grade (99.95%).

PROCEDURE

Pipet 10 mL of sample into a reaction flask. Add 10 mL concentrate HCl. Prepare standards, including a reagent blank, from the 1-ppm selenium stock solution by appropriate microliter additions to 10 mL of distilled water in the reaction flasks and treat similarly.

Attach the reaction flask to the transfer system. Allow at least 10 seconds for the argon to flush out the system and then inject rapidly, but with uniform pressure, 2.5 mL sodium borohydride solution into the reaction vessel using a syringe and 22-gauge needles. Record the absorption signal. Repeat for each standard and sample. Determine concentrations from peak heights.

APPLICATION

This method may be used to analyze solutions containing as little as 0.5 ug/L Se (amount of element which produces 1% absorption).

Representative calibration data are shown in Table 1. The

TABLE 1

CALIBRATION DATA FOR SELENIUM[1]

Selenium Added (μg)	Absorbance	Mean	Standard Deviation	Relative Standard Deviation (%)
Blank	.025, .021, .021	.022	.002	–
.05	.066, .061, .067	.065	.003	4.6
.10	.109, .115, .115	.113	.003	2.7
.15	.151, .151, .149	.150	.001	0.7
.20	.203, .198, .196	.199	.004	2.0
.25	.239, .243, .234	.239	.005	2.1

1. All samples contain 10 mL conc. HCl and 10 mL of water.

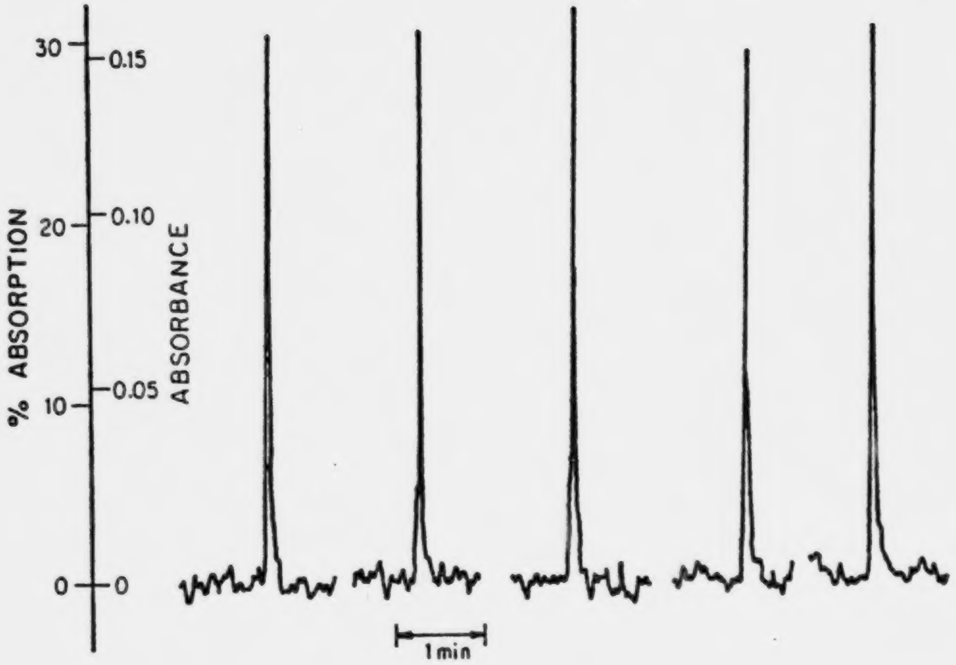
Source: Arthur D. Little, Inc.

relative standard deviations of measured absorbance range from 0.7 to 4.6 over the 0.05 to 0.25 ug Se range. Typical absorption signals for samples containing 0.15 ug Se in 6 M HCl are shown in Figure 2.

INTERFERENCES

No significant effect on the selenium absorbance is observed in the presence of 1000-fold excesses of Mn, Pb, Cu, Fe, Sb, and As in 6 M HCl.

The sensitivity obtained by analyzing standards containing 1.0 mL HCl and 6.5 mL HNO_3 (1.13 abs/ug Se) was found to be only slightly different from the sensitivity in 6 M HCl (1.01 abs/ug Se over the same range). However, the sensitivity obtained by analyzing standards containing no HCl and 7.5 mL HNO_3 (0.36 abs/ug Se) was much less than the sensitivity in 6 M HCl.



Source: Arthur D. Little, Inc.

FIGURE 2 TYPICAL ABSORPTION SIGNALS FOR SAMPLES CONTAINING 0.15 μg SELENIUM IN 1:1 HCl

EXHIBIT D.3-3

COMPARISON OF HYDRIDE EVOLUTION AND GRAPHITE FURNACE METHODS FOR ARSENIC, SELENIUM, ANTIMONY, AND MERCURY

Table 1 summarizes the analysis conditions and precision and accuracy of the various hydride and graphite furnace methods. This summary is included to illustrate the capabilities of these methods and to cover the range of variable operating parameters which will be studied during the method qualification period to determine the applicability of these methods for the various types of samples in this study.

TABLE 1

DATA FOR ATOMIC ABSORPTICN MEASUREMENT OF ARSENIC, SELENIUM, ANTIMONY, AND MERCURY

Analyte	Method	Arthur D. Little, Inc., Method[1]	EPA Method[2]
Arsenic (As)	Hydride Generation	Matrix 4M HCl	$H_2SO_4/HCl/HNO_3$
		Detection Limit 0.5 µg As/L	2 µg As/L
		Precision 0.7 to 4.1% r.s.d. on triplicate samples over 5-30 µg/L range	5.5-9% r.s.d. on 10 replicates over 5-20 µg/L range
		EPA Method[2]	**I.L. Manual Method[3],[4]**
	Graphite Furnace (all candidate methods use Ni matrix modifications)		
	Furnace Conditions: Dry	125°C/30 sec.	ramp to 100°C/50 sec.
	Furnace Conditions: Ash	1,100°C/30 sec	ramp to 1000°C/4 sec
	Furnace Conditions: Atomize	2,700°C/10 sec	2,000°C/10 sec.
	Added Ni Concentrations	1.0%	0.05%
	Reported Range	5-100 µg/L	1-24 µg/L
	Detection Limit	1 µg/L	0.25 µg/L
	Injection Volume	20 µL	25 µL
	Precision	5.4-8.8% r.s.d. over 15-40 µg/L range in waste 1.6-3.5% r.s.d. over 20-100 µg/L range in tap water	

TABLE 1 (Continued)

Analyte	Method		Arthur D. Little, Inc., Method[1]	EPA Method[5]
Selenium (Se)	Hydride Generation		Matrix 6M HCl	$HCl/H_2SO_4/HNO_3$
			Detection Limit 0.5 µg Se/L	2 µg Se/L
			Precision 0.7-4.6% r.s.d. in the 5-25 µg/L range	12-20% r.s.d. on 10 replicates in the 5-18 µg/L range
			EPA Method[6]	**I.L. Manual Method[3,7]**
	Graphite Furnace (all candidate methods use Ni matrix modifications)			
	Furnace Conditions	Dry	125°C/30 sec	ramp to 100°C/45 sec
		Ash	1,100°C/30 sec	ramp to 300°C/40 sec
		Atomize	2,700°C/10 sec	2250°C/5 sec.
	Ni concentration		0.1%	.001% Ni
	Reported Range		5-100 µg/L	2-40 µg/L
	Detection Limit		2 g/L	0.4 µg/L
	Precision		4.1-14.2 r.s.d. over 5-100 µg/L range in water	
			EPA Method[8]	**I.L. Manual Method[3]**
Antimony (Sb)	Graphite Furnace			
	Furnace Conditions	Dry	125°C/30 sec	ramp to 100°C/450 sec
		Ash	800°C/30 sec.	ramp to 400°C/30 sec
		Atomize	2,700°C/10 sec	2,250°C/15 sec.
	Reported Range		20-300 µg/L	6-320 µg/L
	Detection Limit		3 µg/L	3.2 µg/L

TABLE 1 (Continued)

Analyte	Method	NBS Method[9]	EPA Method[10]
Mercury (Hg)	Cold Vapor		
	Sample Preparation	Wet acid digestion in $HNO_3/HClO_4/H_2SO_4$, diluting residue in HF and H_2SO_4	$H_2SO_4/KMnO_4/K_2S_2O_8$ digestion
	Hg Evolution	$SnCl_2$, NaCl, H_2SO_4 in 0.01% dichromate	Hydroxylamine sulfate/NaCl/ stannous sulfate/H_2SO_4
	Quantification	peak height	peak height
	Detection Limit		0.2 ng/mL
	Injection Volume		100 mL
	Precision (single lab)		2-10% r.s.d. over 1-4 μg/L range
	Graphite Furnace	**I.L. Manual Method[3,11]**	
	Furnace Conditions: Dry	150°C/5 sec	
	Furnace Conditions: Ash	275°C/20 sec	
	Furnace Conditions: Atomize	750°C/5 sec	
	Detection Limit	0.1 ng/mL	
	Injection Volume	50 μL	
	Precision	8% r.s.d. over 50-300 μg/L range	

1. Developed as part of EPA Contract 68-02-2443 (As and Se in Stationary Sources).
2. SW 846, Method 8.51 (As) pp. 8.51 – 5 to 10.
3. Instrumentation Laboratories, Atomic Absorption Methods Manual, Volume 2, Flameless Operations.
4. Note that lower recommended atomization temperature and Ni concentration would seem to make the Instrumentation Laboratories cookbook method more attractive; however, in Arthur D. Little's most recent trial of the I.L. method, a 10-20% r.s.d.'s at the 10-15 μg/L range on triplicate analyses was observed.
5. SW 846, Method No. 8.59, pp. 8.59-6.
6. *Ibid.*, pp. 8.59-1.
7. Note the low (.001%) Ni concentration recommended in the I.L. Manual.
8. SW 846, Method No. 8.50.
9. Ref. 5.10.
10. SW 846, Method No. 8.57.
11. Predigestion not required, this may result in considerable time saving.

EXHIBIT D.4-1

PROCEDURE FOR OBTAINING ION CHROMATOGRAMS USING THE DIONEX MODEL 14 SYSTEM EQUIPPED WITH A WISP AUTO INJECTOR

This procedure is written for the Dionex Model 14 ion chromatograph using system #2, equipped with a 150-mm anion precolumn, a 500-mm anion separator column, an anion suppressor column, and a 0.003 M $NaHCO_3$/0.0024 M Na_2CO_3 aqueous eluent.

The suppressor column needs to be regenerated after approximately every 20 hours of operation. If the suppressor column has not been regenerated (check with last operator), perform the regeneration steps; if system has been regenerated skip to step 9.

ANALYSIS AND REGENERATION

1. Fill the bubble trap tube attached to pump #3 with de-ionized water.
2. Set control valves in the front panel of the instrument for system #2 all in the down position except the suppressor switch (last one). The flow sheet should show water flowing only through the suppressor and into the detector.
3. Start pump #2 and adjust flow rate to 90% on the micrometer adjustment located at the right side of the pump. (System pressure should not exceed 600 psi.)
4. Let water run through the suppressor for 10 minutes. (Note the conductivity meter decreasing to that of water [1-10-uMhos] on the log scale.)
5. Stop pump #2.
6. Flip suppressor switch to bypass/Rgn (down position).
7. Make sure water container and 1 N H_2SO_4 containers have solutions in them (if less than 1/4 full, refill).
8. Push regeneration start (green button). (Make sure regeneration timer is set for 15 min and rinse timer is set for 30 min.) Once started, this operation is

automatically performed and stops after 45 minutes when completed.

9. Empty water from bubble trap (see step 1), and replace it with the eluent (Na_2HCO_3/Na_2CO_3 solution).
10. Set pump flow at recommended flow rate for analysis (approx. 25% of full scale or about 2.0 mL/min) (DO NOT switch pump on at this time.)
11. Verify that there is sufficient eluent in the container (in this case 0.003 M $NaHCO_3$/0.0024 M Na_2CO_3 in water) to be able to operate for the entire analysis time at 2.0 mL/min (the container holds 4 L of solution). Air bubbles caught in the line during this operation should be released by inverting the container or by flushing the line with columns and detector bypassed.
12. Flip valves marked E_2, separator, and suppressor on system #2 to the up position (columns engaged) and detector on system #2.
13. Switch pump #2 on. System pressure should pulsate between 400-600 psi (700 psi should not be exceeded).
14. Set conductivity meter sensitivity to 30 uMhos full scale.
15. Set conductivity meter mode to log. Needle will read about 1/2 scale then drop down to 1-10 uMhos with time. This may occur more than once.
16. When meter settles to 1-10 uMhos on log scale, switch to linear scale and adjust to about 2 uMhos (on 30 uMhos scale) using coarse or fine offset. Very little offset should be required. Switch pump #2 off.
17. If using a 2-recorder system (2 sensitivities simultaneously), set recorder #1 to 100 mV full scale.
18. Set recorder #2 to 1000 mV full scale (for 1 or 2 recorder systems).
19. Set scales by switching conductivity meter to zero (on Dionex Model #14) and adjust pens of both recorders to read 20% of full scale.
20. Set specific conductivity switch on Dionex to CAL. Pen

on recorder #2 should settle on approximately 100% full scale. Full scale should be approximately 200 mm of paper divisions. (Using this procedure for example gives actual ranges recorded by recorder #1 as 3 uMhos full scale and recorder #2 as 30 uMhos full scale with the Dionex switch set on 30 uMhos full scale.)

21. Switch both recorders off and condition the system by running pump #2 on for 45 min. (While the system is conditioning, steps 22 and 23 may be performed.)
22. After 45 minutes, set specific conductivity to linear and set both recorders on. Bring response on-scale with offset switch and check for a flat baseline on recorder #1.
23. When baseline is achieved, set recorder #1 on approximately 30% full scale by the coarse/fine offset. (This serves to allow a downward drift in the baseline when temperature fluctuates.)
24. Push start on WISP (See WISP directions in the next section.) Let system run to completion.
25. Switch off recorders manually or automatically after all samples have been processed. Switch pump #2 off.
26. Start regeneration cycle as in step 1.
27. Remove charts and evaluate data.

DIRECTIONS FOR USE OF AUTOMATIC SAMPLE INJECTION APPARATUS (WISP SYSTEM) FOR ION CHROMATOGRAPHY (WISP)

With system power on and eluent running:

1. Place samples in vials and place vials in tray.
2. Place tray into the WISP and close door, the tray will automatically align to proper location.
3. Flip to auto.
4. Set sample no. to zero.
5. Set desired sample injection volume (usually 100 mL) by pressing sample volume button, then pressing 100, then pressing enter.

6. Choose run time (usually chromatogram length for anions is 30 min). Enter by pressing run time, then pressing 30, then pressing enter.
7. Choose number of replicates (1 generally, unless otherwise noted).
8. Check system messages to read:

System Message	Read
66	00
67	00
79	20 (2.0 mL/min purge)

(Example: press system message 66, then press 00, then enter.)

9. After pressing enter for system message 79, press enter once more, wait until system performs all of its automatic functions. System will be ready to start when it reads sample No. 1.
10. Press run when ready to run samples (when baseline has been achieved); system will then purge, and then display error 103. IGNORE the error. The first injection will occur after 10 minutes, and a delay between injections of about two minutes will occur.

ION CHROMATOGRAPHY SOLUTIONS

Standard Anion Solutions

One liter of each of the following solutions should be part of the laboratory supply for preparation of calibration curves and determination of retention times when trying to identify unknown species. A mixed ion standard solution is used to check column set resolution. (For the most accurate standards, oven-dry chemicals at 105°C for one half hour and cool prior to weighing.)

To obtain the following 1000-ppm solutions, dissolve reagent grade chemicals in de-ionized water.

F^-: Dissolve 2.2100 g NaF/liter

Cl^-: Dissolve 1.6484 g NaCl/liter

NO_2^-: Dissolve 1.4998 g $NaNO_2$/liter

PO_4^{-3}: Dissolve 3.7710 g $Na_2HPO_4 \cdot 12\ H_2O$/liter (undried)

Br^-: Dissolve 1.2877 g NaBr/liter

NO_3^-: Dissolve 1.3707 g $NaNO_3$/liter

SO_4^{-2}: Dissolve 1.8142 g K_2SO_4/liter

To prepare a mixed dilute anion standard solution, add in a 1-liter volumetric flask and dilute to 1 liter with de-ionized water the following quantities of 1000-ppm standard solutions:

F^- solution:	3 mL = 3 ppm
Cl^- solution:	4 mL = 4 ppm
NO_2^- solution:	10 mL = 10 ppm
PO_4^{-3} solution:	50 mL = 50 ppm
Br^- solution:	10 mL = 10 ppm
NO_3^- solution:	30 mL = 30 ppm
SO_4^{-2} solution:	50 mL = 50 ppm

Various other standard mixes for different analyte concentrations may be made.

Regeneration Solution (1 N H_2SO_4)

To prepare a sulfuric acid solution for regeneration of the anion suppressor column, dilute 111 mL conc. H_2SO_4 in 4 L DI H_2O; or dilute 555 mL conc. H_2SO_4 in 20 L DI H_2O.

Standard Eluent for Anion Analysis (0.003 M $NaHCO_3$, 0.0024 M Na_2CO_3)

The standard eluent solution for anion analysis is prepared by dissolving 1.0080 g $NaHCO_3$ and 1.0176 g Na_2CO_3 in 4 L DI H_2O, (or 5.0400 g $NaHCO_3$ and 5.0880 g Na_2CO_3 in 20 L DI H_2O).

General eluents should be prepared from filtered DI or distilled water and reagent-grade chemicals. They are normally prepared in 4-liter collapsible bottles which are placed in labeled cardboard boxes. After measuring 4.0 liters of water into a bottle, outline the top of the water line with a pen to reduce future preparation time. Also 5-gallon carboys (or 20 liters) of eluent may be prepared for long-term use. Equilibrium time for the eluents depends on temperature, the particular eluents being prepared and the columns. For all except very warm solutions, one half hour to one hour is sufficient.

EVALUATION OF IC DATA

1. Use form shown in Figure 1 to summarize the data. Plot peak height (or area) vs. concentration.
2. Data are reported for F^-, Cl^-, NO_3^-, $SO_4^=$ and any other identified peaks.

Sheet____ of ____

Chart No. ________

Date __/__/__ Client ____________ Case No. ________ Operator's Signature ____________

Analysis: Anion ☐ Cation ☐ ICE ☐ Precolumn No. ________ Column No. ________ Column Type ________

Suppressor Column No. ________ Eluent ________ Flow Rate ________ mL/min. Pump % ________

No. of Inject. ____ Inject. Vol. ____ μL Run Time ____ min. Chart Speed ____ cm/min Chart Sc. ____ μMho

Vial No.	Sample Code	SPECIES IDENTIFICATION											
		R.T.		R.T.		R.T.		R.T.		R.T.		R.T.	
		Peak Height Area	☐ Conc. ☐ μg/mL	Peak Height Area	☐ Conc. ☐ μg/mL	Peak Height Area	☐ Conc. ☐ μg/mL	Peak Height Area	☐ Conc. ☐ μg/mL	Peak Height Area	☐ Conc. ☐ μg/mL	Peak Height Area	☐ Conc. ☐ μg/mL
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													

*Below Base Line

**Below Detection Limit

FIGURE 1 ION CHROMATOGRAM RECORD

EXHIBIT D.5-1

MEASUREMENT OF pH

Measurement of pH using this procedure may be made on liquid or slurry samples in the field and/or in the laboratory.

The pH can be measured with any glass reference (i.e., saturated calomel) electrode set provided that the following points are observed:

1. The glass electrode must be clean and free of cracks and other marks. A wide-range (0-14 pH) industrial-quality electrode is recommended. A new glass electrode should be soaked in water (of pH4 buffer solution) for one half hour before use.
2. The reference electrode must be filled with the appropriate electrolyte (generally 4 M KCl saturated with AG^+) for the calomel electrode. Electrical conductivity through the liquid junction must be confirmed (generally indicated by different response for different pH buffers). A sleeve-type junction is best for this purpose, although the electrolyte level must be checked frequently since the electrolyte leakage rate tends to be high with this junction.
3. The electrode pair or combination electrode must be set (i.e., standardized) using a standard buffer reasonably near the expected sample pH, and cross-checked against a buffer beyond the expected sample pH. This latter check is extremely important to prove the linearity of electrode response in the region of interest. Provided that fresh buffers are used, the indicated pH should be within 0.1 pH unit for the check (second) buffer. At least three buffers should be used. The manufacturer's instructions should be referred to for a detailed procedure.
4. Care should be taken in limiting exposure of the sample to the atmosphere (i.e., minimal agitation during analysis).

Additional information can be obtained in Reference 7.18.

EXHIBIT D.5-2

ANALYSIS OF TOTAL DISSOLVED SOLIDS (TDS)

SCOPE AND APPLICATION

The purpose of this analysis is to evaluate the amount of dissolved solids in various liquids. The samples will include liquid aliquots from ash slurries, FGC waste liquors, groundwater, and surface waters.

SUMMARY OF METHOD

An aliquot of filtered liquid is dried completely at 120°C and the residue weighed.

APPARATUS

- Clean 150-mL beakers
- Drying oven equipped with a thermostatic control capable of maintaining the temperature within a 2°C range
- Desiccator, provided with a desiccant containing a color indicator of moisture concentration
- Analytical balance, 200-g capacity, capable of weighing 0.1 mg
- 50-mL volumetric pipets

REAGENTS

None required

PROCEDURE

1. A clean 150-mL beaker is placed in the drying oven at 120°C overnight. After heating, it is placed in the desiccator, cooled, and then weighed.
2. The beaker is then replaced in the oven and heated for 1 hour at 120°C, desiccated, and weighed to constant

weight.

3. A 50-mL aliquot of the sample is pipetted into the tared beaker.
4. The beaker is placed in the oven overnight at 120°C.
5. The solids are desiccated and weighed according to desiccator procedures.

CALCULATION

$$\frac{(A\text{-}B) \times 10^{-6}}{C} = \text{mg/L TDS at } 110^{\circ}\text{C}$$

where A = weight of dried residue and beaker in grams;
B = weight of beaker in grams; and
C = mL filtrate used.

EXHIBIT D.5-3

PROCEDURES FOR ANALYSIS OF SULFITE AND TOTAL OXIDIZABLE SULFUR (TOS)

Three sulfite and/or TOS procedures are included in this section. (See Reference 7.19.) The first two are for high levels in solids and liquids and the third is for trace levels in liquids. High levels of sulfite are measured by reaction with iodine and back titration with thiosulfate. Trace levels may be measured using a modified West-Gaeke colorimetric procedure.

TOTAL OXIDIZABLE SULFUR (TOS) IN LIQUIDS (HIGH LEVELS)

1. Transfer 30 mL (measured to +.02 mL) of 0.1 I_2 solution into a 125-mL Erlenmeyer flask and cover with a watchglass. Note: Experience may show that some samples may require more or less iodine.
2. Add approximately 20 mL of distilled water and 2 mL of glacial acetic acid. In lieu of acetic acid, 15 mL of 0.1 N HCl may be used.
3. Pipet 2 mL of sample (volumetric pipet) directly into the acidified iodine solution while swirling the solution to assure rapid mixing of the sample. If all iodine color is discharged, repeat the procedure using more I_2 solution and adjust calculations accordingly.
4. Back titrate with 0.1 N $Na_2S_2O_3$ to pale yellow color. Add starch solution to give blue color and continue dropwise addition of titrant to disappearance of blue color.
5. Calculations:

$$\text{TOS (moles/L)} = \frac{[(\text{mL } I_2)(\text{N } I_2)] - [(\text{mL } S_2O_3)(\text{N } S_2O_3)]}{(2)(2\text{mL})}$$

where

N I_2 is the normality of the I_2 solution;

N S_2O_3 is the normality of the $Na_2S_2O_3$; and

2 is the equivalence factor for moles of oxidizable sulfur.

TOTAL OXIDIZABLE SULFUR (TOS) IN SOLIDS

1. Weigh out from 0.11 to 0.12 g (weighed to i.e., +0.0001 g) of solids on a weighing paper or boat.
2. Transfer 25 mL of 0.1 N I_2 solution into a 250-mL Erlenmeyer flask. Add approximately 75 mL of distilled water and 10 mL of 10% HCl.
3. Quick transfer the weighed solids to the iodine solution and cover the flask with a watchglass.
4. Stir the suspension until all of the solids have dissolved. A magnetic stirrer is useful for this operation. Break up any lumps with a glass rod. Note: In solids with a very high $CaSO_4$ content, not all of the solids will dissolve in the acid. In general, all solids should dissolve in 30 minutes.
5. As soon as all solids have dissolved, back titrate the excess I_2 with 0.1 N $Na_2S_2O_3$. When the solution has reached a pale yellow color, add starch solution to give a blue color. Continue the titration dropwise until the blue color is discharged.
6. Carry at least one reagent blank through the process, using the same length of stirring time as for the sample. This will help to ascertain whether air oxidation is causing an interference in the method. The blank titer (volume of $Na_2S_2O_3$ per volume of I_2 taken) should be within 0.005 of the standardization titer.

7. Calculations:

$$\text{TOS (millimoles/g)} = \frac{(\text{mL } I_2 \times \text{N } I_2) - (\text{mL } S_2O_3 \times \text{N}S_2O_3)}{(2)\ (\text{g sample})}$$

where

N I_2 and N S_2O_3 are the normalities of the I_2 and $Na_2S_2O_3$ solutions; and

2 is the equivalence factor for moles of oxidizable sulfur.

DETERMINATION OF LOW CONCENTRATIONS OF SULFITE IN WATER

Principle: Sulfite in an aqueous sample is determined by an extension of the method of West and Gaeke* in which sulfite is stabilized by reaction in tetrachloromercurate ion and measured by colorimetry using a formaldehyde/p-rosaniline color reagent.

Reagents: Na_2HgCl_4 solution, 0.04 M, prepared by dissolving 10.86 g $HgCl_2$ and 4.68 g NaCl in 1 L volume with H_2O

Para Rosaniline stock solution, 0.2% in 1 M HCl obtained from Eastman Chemicals

Phosphoric Acid, 85%

Phosphoric Acid, 3 M, prepared by diluting 205 mL of 85% into 1 L volume with H_2O

Formaldehyde, 36-38%

Formaldehyde Reagent, approximately 0.02 M, prepared by dissolving 1.25 g of Na_2SO_3 in 500 mL of deoxygenated water under a nitrogen atmosphere; standardize by back titration with iodine and thiosulfate. Store under nitrogen.

I_2 solution, 0.1 M

Dilute Na_2SO_3 standard solution, approximately 4×10^{-4} M; prepare by dilution of 2 mL of

approximately 0.02 M in 100-mL volume of
deoxygenated water. Prepare immediately before
use and maintain under a nitrogen atmosphere
while sampling the solution.

Nitrogen, purified

Spectrophotometer equipped with two 1-cm cells

Procedure:

1. Pipet 200 mL of the Na_2HgCl_4 solution into a 50-mL volumetric flask which is covered with aluminum foil to protect it from light. Deoxygenate the solution by bubbling N_2 through it for 10 minutes.
2. Pipet 2 mL sample [concentration $(1-4) \times 10^{-4}$ M sulfite] into the solution inserting the tip of the pipet under the surface of the liquid. The sulfite is now stabilized, and these samples can be stored for several hours as long as they are protected from light. For higher concentrations of sulfite, stabilize 2 mL of sample and take an aliquot containing $(2-8) \times 10^{-4}$ moles of sulfite.
3. Prepare a set of standard stabilized solutions, covering the range of $(4-20) \times 10^{-6}$ M, using 0.5 to 2.0 mL of the dilute standard sulfite solution in place of the samples. Analyze these standards simultaneously with the samples.
4. Pipet 4 mL of 0.2% formaldehyde solution into all of the samples and standards.
5. Pipet 10 mL of the para-rosaniline reagent into all the flasks and start a laboratory timer that has been set for 30 minutes after addition to the first flask.
6. After addition of the reagents, bring all the flasks to volume (50 mL) with distilled water which has been deoxygenated by sparging with nitrogen for 10 minutes just prior to use.
7. After 30 minutes determine the absorbance of the samples, standards, and blank, at 548 nm versus

distilled water. If the absorbance of the blank exceeds 0.12, the measurements must be repeated with new reagents.

8. Prepare a calibration curve by plotting the corrected absorbance (Abs_{sample} - Abs_{blank}) vs. concentration of sulfite.
9. Determine the concentration of sulfite in the samples by comparing the corrected absorbance (Abs_{sample} - Abs_{blank}) of the samples with the standard curve.

An example of a typical calibration curve is given in Figure 1. The sulfite concentrations given are those present in the measured solution. If the absorbance of the sample is outside of the calibration range, an aliquot of the stabilized sulfite solution may be taken to bring the concentration to the measurable range.

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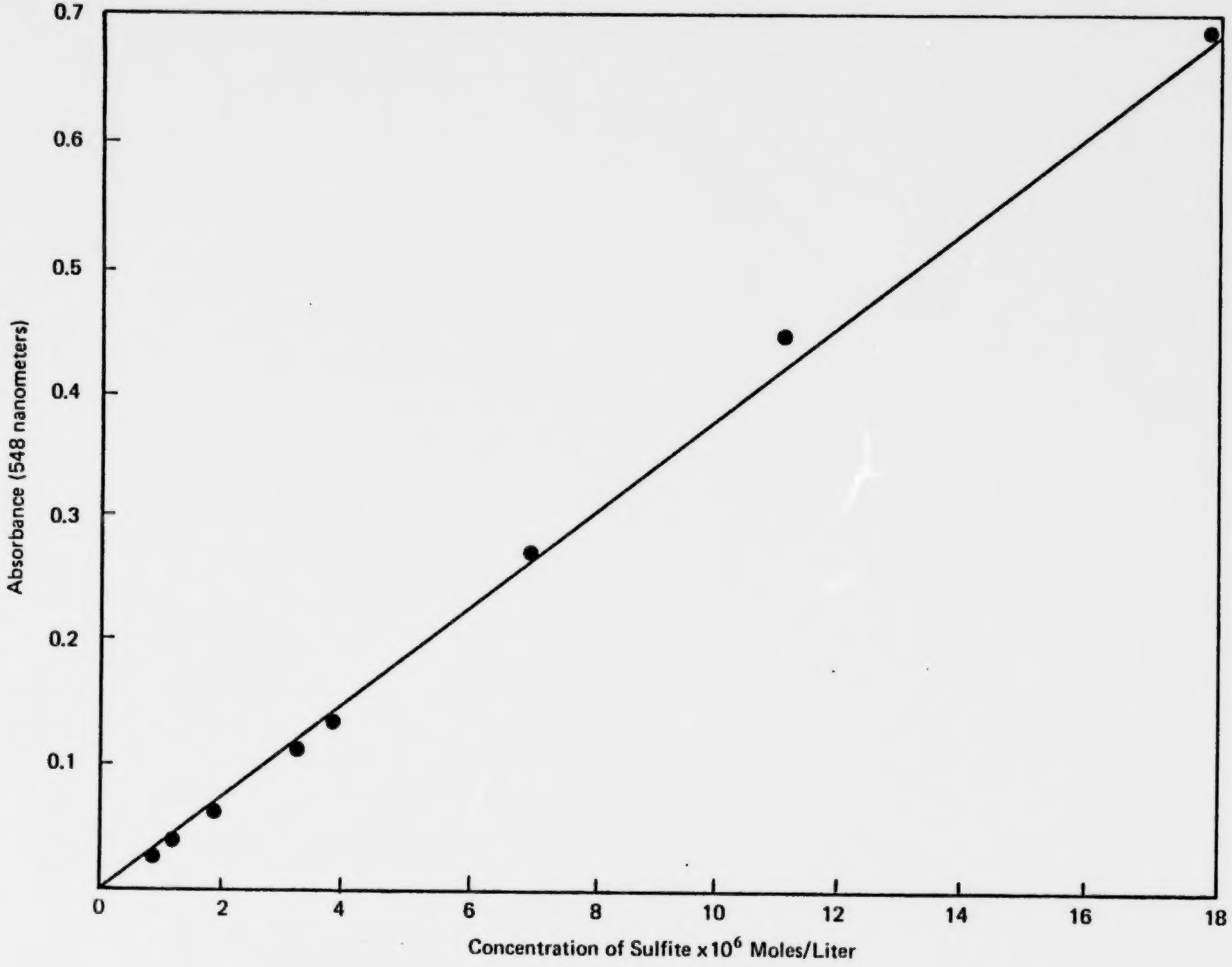
*Anal. Chem. 28, 1816, 1956.



Source: Arthur D. Little, Inc.

FIGURE 1 EXAMPLE OF CALIBRATION CURVE FOR PARA ROSANILINE-SULFITE REACTION PRODUCT

EXHIBIT D.5-4

MEASUREMENT OF ALKALINITY/ACIDITY/CARBONATE

The following procedures are given for determining the hydroxide carbonate, bicarbonate of various samples using several alkalinity measurements. These are:

- Phenolphthalein alkalinity;
- Total alkalinity by mixed bromocresol green-methyl red indicator method;
- Total alkalinity by methyl-orange indicator method;
- Potentiometric titration of low alkalinity;
- Thymolphthalein alkalinity in solids and liquids; and
- Thymolphthalein acidity in liquid samples.

Use sample volumes requiring less than 25 mL of titrant because they yield the sharpest color changes at the end point. If indicator methods are used, remove the free residual chlorine by adding 0.05 mL (1 drop) 0.1 N sodium thiosulfate solution or by ultraviolet irradiation.

PHENOLPHTHALEIN ALKALINITY

Add 0.1 mL (2 drops) phenolphthalein indicator to a sample of suitable size, 50 or 100 mL if possible, in an Erlenmeyer flask. Titrate over a white surface with 0.02 N standard acid to the coloration corresponding to the proper equivalence point of pH 8.3.

TOTAL ALKALINITY BY MIXED BROMOCRESOL GREEN-METHYL RED INDICATOR METHOD

Add 0.15 mL (3 drops) indicator to the solution in which the phenolphthalein alkalinity has been determined, or to a sample of suitable size, 50 or 100 mL if possible, in an Erlenmeyer flask. Titrate over a white surface with 0.02 N standard acid to the proper equivalence point. The indicator yields the following color responses: above pH 5.2, greenish blue; pH 5.0, light blue with lavender gray; pH 4.8, light pink-gray with a bluish cast; pH 4.6, light pink.

TOTAL ALKALINITY BY METHYL ORANGE INDICATOR METHOD

Add 0.1 mL (2 drops) indicator to the solution in which the phenolphthalein alkalinity has been determined, or to a sample of suitable size, 50 or 100 mL if possible, in an Erlenmeyer flask. Titrate over a white surface with 0.02 N standard acid to the proper equivalence point. The indicator changes to orange at pH 4.6 and to pink at 4.0.

POTENTIOMETRIC TITRATION OF LOW ALKALINITY

For greatest accuracy, titrate low alkalinites (less than 10 mg/L) potentiometrically rather than by indicator methods. Potentiometric titration avoids the error due to the sliding end point caused by free CO_2 in the sample at completion of the titration.

With a microburette, titrate carefully a sample of suitable size, 100 to 200 mL, and record the volume C (in mL) of standard acid titrant (normality N) required to reach a pH of 4.5. Continue the titration to pH 4.2 and record the total volume D (in mL) of acid titrant. (Precise standardization of the pH meter is unnecessary.)

Calculations

1. Indicator Methods

$$\text{Phenolphthalein alkalinity as mg/l } CaCO_3 = \frac{A \times N \times 50{,}000}{\text{mL Sample}}$$

$$\text{Total alkalinity as mg/L } CaCO_3 = \frac{B \times N \times 50{,}000}{\text{mL Sample}}$$

2. Potentiometric Method for Low Alkalinity

$$\text{Total alkalinity as mg/L } CaCO_3 = \frac{(2C - D) \times N \times 50{,}000}{\text{mL Sample}}$$

where

A = mL titration for sample to reach the phenolphthalein end point;

B = total mL titration for sample to reach the second end point;

C = mL titration for sample to reach pH 4.5;

D = total mL titration for sample to reach pH 2.4; and

N = normality of acid.

Note: If total alkalinity is determined on the sample used for phenolphthalein alkalinity, be sure to include the volume of acid required for the phenolphthalein titration, A, in the total milliliters, B, of standard acid.

Calculation of Alkalinity Relationships

The results obtained from the phenolphthalein and total alkalinity determinations offer a means for the stoichiometric classification of the three principal forms of alkalinity present in many water supplies. The classification ascribes the entire alkalinity to bicarbonate, carbonate, and hydroxide, and assumes the absence of other (weak) acids of inorganic or organic composition, such as silicic, phosphoric, and boric acids. This classification system further presupposes the incompatibility of hydroxide and bicarbonate alkalinities in the same sample. Since the calculations are made on a stoichiometric basis, ion concentrations in the strictest sense are not represented in the results. According to this scheme:

1. Carbonate alkalinity is present when the phenolphthalein alkalinity is not zero but is less than the total alkalinity.
2. Hydroxide alkalinity is present if the phenolphthalein

alkalinity is more than half the total alkalinity.

3. Bicarbonate alkalinity is present if the phenolphthalein alkalinity is less than half of the total alkalinity.

The mathematical conversion of the results is shown in Table 1.

TABLE 1

ALKALINITY RELATIONSHIPS[1]

Result of Titration	Hydroxide Alkalinity as $CaCO_3$	Carbonate Alkalinity as $CaCO_3$	Bicarbonate Alkalinity as $CaCO_3$
$P = 0$	0	0	T
$P < 1/2T$	0	2P	T-2P
$P = 1/2T$	0	2P	0
$P > 1/2T$	2P-T	2(T-P)	0
$P = T$	T	0	0

1. P-phenolphthalein alkalinity; T = total alkalinity.

THYMOLPHTHALEIN ALKALINITY IN SOLIDS AND LIQUIDS

Hydroxide (Solids)

1. Weigh out from 0.50 mg to 0.55 g (weighed to +0.0001 g) of sample and transfer to a 125-mL Erlenmeyer flask containing 40 mL of distilled water and magnetic stirring bar.
2. Add 2 to 3 drops of thymolphthalein indicator solution and 10 mL of 2.5% calcium chloride solution.
3. Titrate with 0.1 N HCl to the disappearance of the blue color. The indicator color may reappear on continued stirring. The titration should be continued until the end point holds for at least one minute. Note: If too much indicator has been added, the end point is seen as a marked decrease in the intensity of the blue color.
4. Calculations:

$$\text{Hydroxide (millimoles/gram)} = \frac{(\text{mL HCl})(\text{NHCl})}{\text{g sample}} .$$

Hydroxide (Liquids)

1. Pipet a 10-mL aliquot of sample into a 125-mL Erlenmeyer flask. Add approximately 25 mL of distilled water, 10 mL of 2.5% calcium chloride solution, and 2 to 3 drops of thymolphthalein.
2. Titrate with 0.1 N HCl to the disappearance of the blue color. Note: If too much indicator has been added, the end point is seen as a marked decrease in the intensity of the blue color, rather than complete disappearance.
3. Calculations:

$$\text{Hydroxide (moles/L)} = \frac{(\text{mL HCl})(\text{NHCl})}{10} .$$

THYMOLPHTHALEIN ACIDITY IN LIQUID SAMPLES

Acidity measurements may be made on ash liquors. Interpretation of the acidity must include data on any resultant precipitation of metals during the titration which consumes alkalinity. The following procedure is given for samples which contain negligible concentrations of metals which precipitate in the pH 4-10 region.

Acidity Liquids

1. Transfer 15 mL (±.01 mL) of 0.1 N NaOH solution into a 125-mL Erlenmeyer flask, and add 2 to 3 drops of thymolphthalein indicator solution.
2. Pipet a 10-mL aliquot of sample into the NaOH solution and mix well.
3. If solution remains blue, titrate with 0.1 N HCl to disappearance of blue. Note: If too much indicator has been added, the end point is seen as a marked decrease in intensity of the blue color when 1 to 2 drops of HCl are added.
4. If indicator color disappears during addition of sample and does not reappear upon mixing, repeat the determination using a larger aliquot of 0.1 N NaOH.
5. The exact N of the NaOH is determined by titrating a known volume (15 mL ±.01 mL) with 0.1 N HCl to the thymolphthalein endpoint. Then

$$\text{N NaOH} = \frac{\text{mL HCl}}{\text{mL NaOH}} \times (\text{N of HCl}) \quad .$$

6. Calculations:

$$\text{Acidity (moles/L)} \;=\; \frac{[(\text{mL NaOH})(\text{N NaOH})] - [(\text{mL HCl})(\text{N HCl})]}{10\ \text{mL}}$$

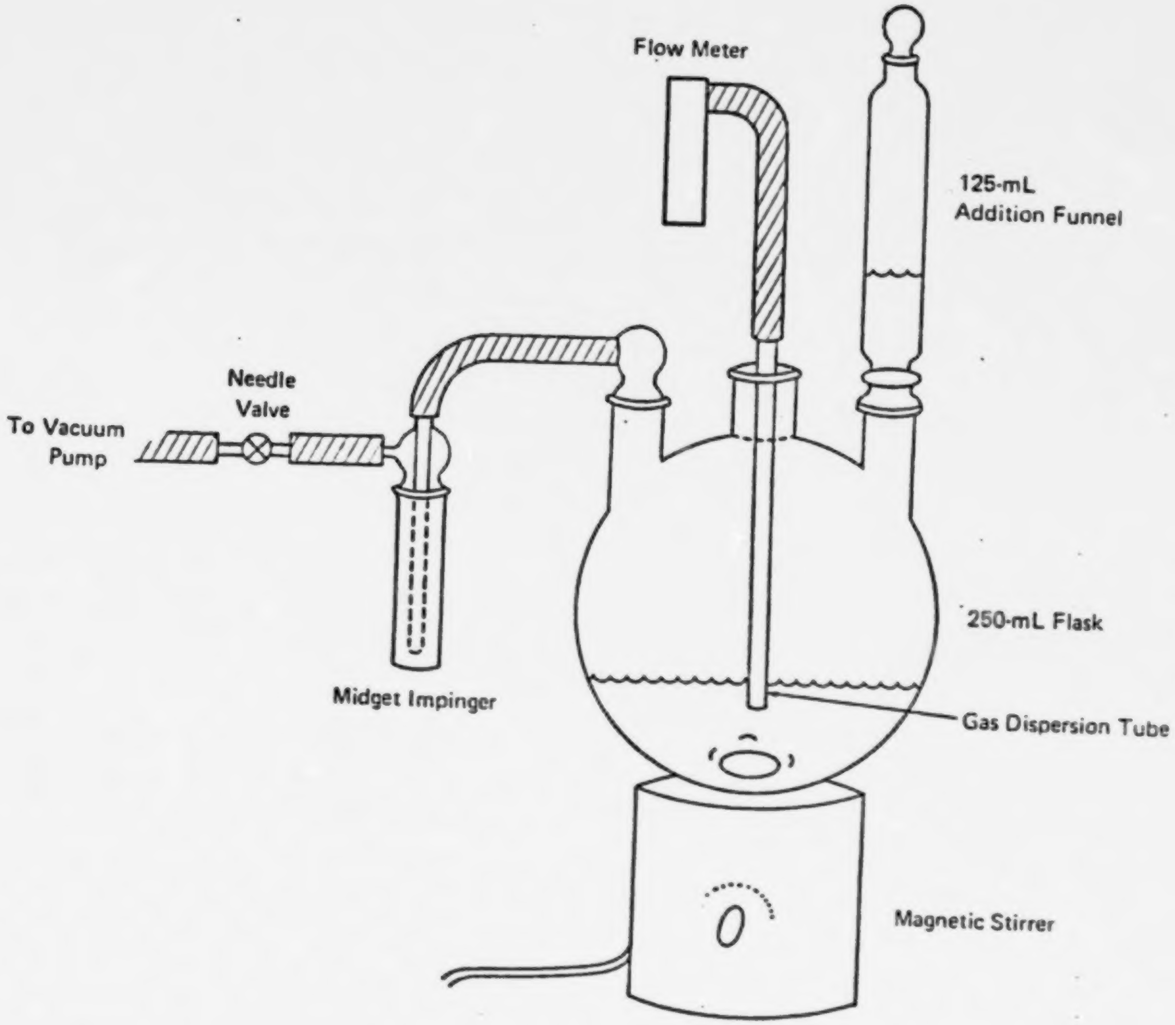
where N NaOH = the exact normality determined above.

EXHIBIT D.5-5

PROCEDURES FOR ANALYSIS OF CARBONATE (IN SOLIDS)

Because calcium is present in many FGC waste solids, the carbonate is separated and measured as CO_2 after first oxidizing all sulfite species to sulfate. Note: Once the determination is started, it must be carried through step 13 (acid to bromocresol green) in order to avoid error from absorption of atmospheric CO_2.

1. Set up the apparatus shown schematically in Figure 1. Three midget impingers or midget bubblers in series will give a 98% collection efficiency for CO_2.
2. Just prior to performing the analysis, place 50 mL of 0.1 N HCl and 3 mL of methyl red indicator solution into the addition funnel. Also transfer 15 mL of 0.5 N NaOH into each of the midget impingers.
3. Transfer between 1.0 and 1.1 g (weighed to +0.0001 g) of the solids into the reactor, and add a magnetic stirring bar and 50 mL of distilled water.
4. Add 1 drop of phenolphthalein solution, and then add 0.1 N NaOH dropwise until a permanent faint pink color is seen in solution.
5. Add 5 mL of 30% hydrogen peroxide and immediately seal the system. Then start the magnetic stirrer.
6. Start the sparging system and adjust to give an air flow of approximately 2 liters/minute.
7. Add the 0.1 N HCl slowly into the reactor until the yellow color (from the methyl red) turns red.
8. Continue stirring and sparging until all the solids dissolve. It may be necessary to add more the of 0.1 N HCl dropwise in order to achieve complete solution.
9. Once all solids have dissolved, continue the purge for 15 more minutes.
10. Transfer the impinger solutions to a 150-mL beaker washing the impinger with distilled water to effect quantitative transfer.


Flow Meter
125-mL
Addition Funnel
Needle
Valve
To Vacuum
Pump
250-mL Flask
Midget Impinger
Gas Dispersion Tube
Magnetic Stirrer

Source: Arthur D. Little, Inc.

FIGURE 1 APPARATUS FOR CARBONATE IN SOLIDS

11. Add 1 mL of 30% H_2O_2; mix and let stand 15 minutes (covered).

12. Add 1 mL of the 10-mg/liter manganese solution and boil the solution (covered with a watchglass) for 5 minutes. Cool the solution to near room temperature quickly (to minimize exposure to atmospheric CO_2).

13. Add to the impinger solution 1 drop of phenolphthalein solution and 5 mL (pipet) of 1 N HCl.

14. Titrate with 0.1 N HCl to disappearance of pink color. Note: if too much indicator has been added, the end point is seen as a marked decrease in intensity of the red color. Note the volume (level) of 0.1 N HCl in the burette, and call this "A."

15. Add 3 to 4 drops of bromocresol green indicator solution to titration solution, and continue titration with 0.1 N HCl until a permanent yellow color is seen. Then add 3 mL of titrant in excess. Note the reading of the HCl burette and call this "B."

16. Quantitatively transfer the titrated solution to a 150-mL beaker and boil (uncovered) for 10 minutes. Note: It may be necessary to add small amounts of distilled water during the boiling in order to avoid spattering losses.

17. Cool the solution and back-titrate with 0.1 N NaOH to a green end point. Call this volume "C."

18. Run at least one blank determination including sparging for the same amount of time.

19. Calculations:

$$\text{Millimoles carbonate} = [(B-A) \times N\ HCl] - [C \times N\ NaOH]$$

$$\frac{\text{Carbonate (millimoles/g)} = (\text{millimoles } CO_3 \text{ in sample}) - (\text{millimoles } CO_3 \text{ in blank})}{\text{g sample}}$$

where

N HCl = normality of HCl; and

N NaOH = normality of NaOH to bromocresol

A = mL titration for sample to reach phenolphthalein end point.

B = total mL titration of acid added.

C = mL of NaOH for back titration to bromocresol green end point.

EXHIBIT D.5-6

DETERMINATION OF THE QUANTITY OF ACID INSOLUBLE MATERIAL*

This procedure is applicable to FGC waste solids which are mixtures of ash and FGD materials. An approximate measure of ash content can be obtained using this procedure.

1. Add a 0.5- to 1.0- g sample to 40 mL of 1 N HCl.
2. Stir the mixture or shake it for 1 hour.
3. Filter the resultant slurry through a Millipore AA tared filter.
4. Dry the resultant filter and solids at 85°C to constant weight.
5. Calculation:

$$\%\ \text{Acid Insolubles} = \frac{\text{weight of dried residue}}{\text{weight of sample taken}} \times 100.$$

---

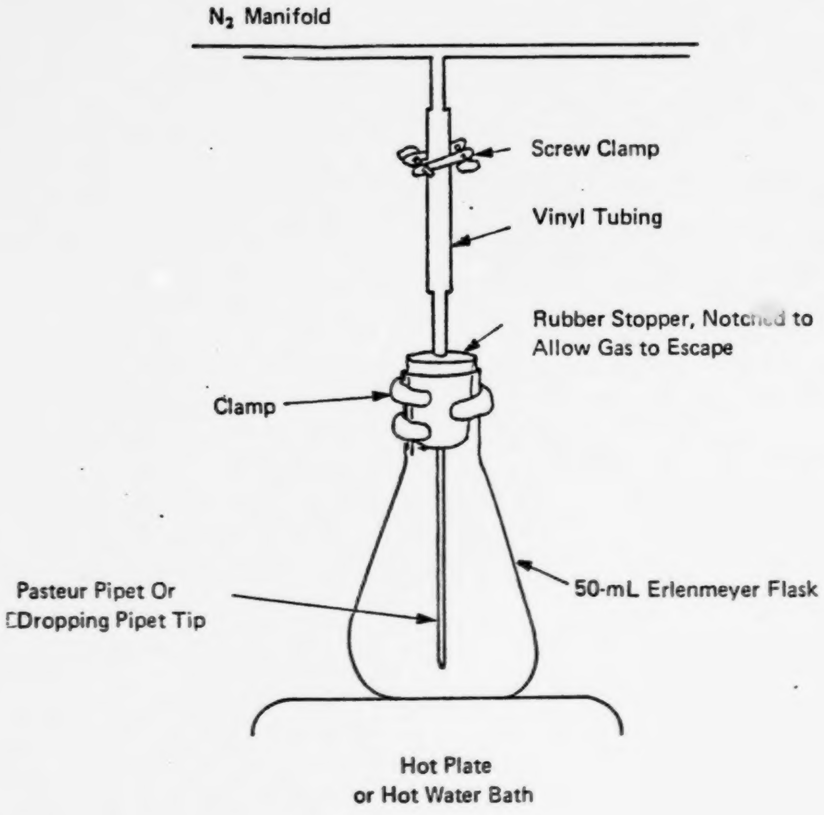
* This corresponds only to that portion of the sample which is insoluble in 1 N HCl.

EXHIBIT D.5-7

PROCEDURES FOR SULFATE ($SO_4^=$) ANALYSES

This method is applicable to solid samples. (Analysis of sulfate in liquid samples will be done by oxidation of the sulfite, measurement of total sulfur by ion chromatography after dilution, and subtracting the TOS originally present in the liquid.)

1. Set up the sparging/boiling apparatus as shown in Figure 1, and add 30 mL of distilled water to the Erlenmeyer flask(s).
2. Heat the water to boiling and purge with a gentle nitrogen flow for 3 minutes to remove dissolved oxygen.
3. Transfer 0.3 to 0.4 g (weighed to +0.0001 g) of sample to the purged water.
4. Purge with nitrogen for 3 minutes more, then quickly add 10 mL of 1 M perchloric acid (restopper flask quickly) to dissolve sample.
5. When all solids have dissolved, bring to a boil and purge for at least 30 minutes (no less). Then cool solution.
6. Transfer the solution to a 150-mL beaker, add 2 drops bromocresol green indicator, and neutralize (to within 1 drop on the acid, yellow, side) with 1 M NaOH and 1 M $HClO_4$.
7. Add 5 g of washed cation exchange resin, and mix (magnetic stirrer) for 30 minutes.
8. Filter the solution and resin through a 1-inch thick bed of the same resin contained in a sintered glass filter crucible, and wash through with distilled water. The total volume of solution plus washes should be less than 100 mL. Note: This ion-exchange operation can also be carried out on a column containing 10 g of resin.


N_2 Manifold
Screw Clamp
Vinyl Tubing
Rubber Stopper, Notched to Allow Gas to Escape
Clamp
Pasteur Pipet Or Dropping Pipet Tip
50-mL Erlenmeyer Flask
Hot Plate or Hot Water Bath

Source: Arthur D. Little, Inc.

FIGURE 1 APPARATUS FOR SULFATE DETERMINATION

9. Allow to cool and transfer purged solution into a 150-mL beaker. Add 2 drops bromocresol green indicator solution and neutralize solution with 1 N NaOH adding one drop of $HClO_4$ after indicator has turned green.
10. Add 10 mL of 1 M $NaClO_4$ solution and enough methanol to make a 50% (v/v) solution.
11. Under rapid stirring, add 25 mL of standardized (0.1 M) lead perchlorate solution. The amount of lead added should be such that an excess of lead remains in solution. If necessary, readjust pH of solution to 3.5 to 4-5 with $HClO_4$ or NaOH.
12. Back titrate the excess lead with 0.2 M Na_2SO_4 solution using the EMF between the lead-selective specific ion electrode and the double-junction reference electrode to indicate the end point. Titrant increments at the end point should be 0.1 mL. The end point region can be seen from the daily standardization curve, and may vary because of changes in the condition of the lead electrode. The end point can be determined graphically or by means of the second derivative technique.
13. Calculations:

$$\frac{\text{Sulfate (millimoles/g)} = [(\text{mL lead perchl.})\,(\text{M lead perchl.})] - [(\text{mL } Na_2SO_4)\,(\text{M } Na_2SO_4)]}{\text{g sample}}$$

EXHIBIT D.6-1

MEASUREMENT OF RADIOACTIVITY IN VARIOUS SOLID AND LIQUID SAMPLES AND FROM THE SITE

SOLIDS

Radioactivity in the solid phase will be characterized by 226-radium (^{226}Ra) concentration.

Two methods are suggested for ^{226}Ra. The first, involving a considerable amount of wet chemistry, is based on measuring radon emanation from the dissolved sample. This method is specific to ^{226}Ra and so has little or no interference from other nuclides. The second method, based on gamma-ray spectroscopy of the ^{226}Ra daughter products, is somewhat less specific than the radon emanation method, but involves no wet chemistry and so provides major savings in the analysis effort. In addition, the second method uses samples of 0.5 kg, while the first uses 1-g samples.

^{226}Ra by Radon Emanation

Samples containing up to 1 g inorganic matter are used. Treatment follows that of ^{226}Ra analyses of suspended matter as in Reference 7.20, or EPA modification of this method. The procedure includes ashing, grinding, alkaline fushion, acid dissolution of the fushion, sealing the solution for a known period (preferably seven days or longer, for grow-in of ^{222}Ra daughters), de-gassing of the ^{222}Ra into a calibrated alpha particle-sensitive scintillation chamber and alpha counting. Correction is made for grow-in of radon.

^{226}Ra by Sealed Sample Gamma Ray Spectroscopy

Samples containing 50 g matter are sealed in gas-tight thick polyethylene jars or bags for periods of seven days or more. Intensity of the 1.76 MeV gamma ray of ^{214}Bi, a short-lived radioactive daughter product formed in the decay chain of ^{226}Ra, is measured using a calibrated low-background NaI[T1] scintillation or [Li] semiconductor detector. Energy range monitored in the NaI:T1 crystal is 1.6 to 1.9 MeV. Background of the counting system with empty jars or bags is subtracted to give net activity of the sample. Correction is made for grow-in of the activity. The method has been routinely used to determine concentrations of ^{226}Ra in soils, rocks, and bones. (See Reference 7.21.)

LIQUIDS

Radioactivity in the liquid phase or in liquid extracts of the solid phase is to be characterized by analysis of ^{226}Ra, ^{228}Ra, total alpha, and total beta activities.

^{228}Ra by Barium Coprecipitation

In order to isolate ^{228}Ra from the nuclides from which it is formed, the ^{228}Ra must be removed from solution. The method is based on barium coprecipitation of all the radium in solution, drying the precipitate to form a thin layer (not to exceed 10 mg dried matter per sq cm of precipitate) on a planchet and measuring the beta activity of the ^{228}Ra daughter product, ^{228}Ac. ^{228}Ra emits only a weak beta particle, but its first daughter ^{228}Ac emits a 1.11 MeV beta. The ^{228}Ac grows into the newly formed radium precipitate with a 6.1-hour half life. A gas flow-through proportional counter with voltage set for beta counting is used to determine the beta activity of the sample. (See Reference 7.15.)

226-Radium by Barium Coprecipitation

The barium coprecipitation of ^{228}Ra carries with it ^{226}Ra. If the precipitate on the planchet does not exceed 5 mg matter per sq cm, the same sample can be used for ^{226}Ra and ^{228}Ra determination. The thinner precipitate is required since ^{226}Ra emits 4.78 MeV alpha particles. A gas flow-through proportional counter with voltage set for alpha counting is used. (See Reference 7.22.)

An alternative method for ^{226}Ra in water consists of storing

An alternative method for ^{226}Ra in water consists of storing the outgassed water in a radon-tight container for a known time, peferably exceeding seven days. De-gas and measure the ^{222}Rn in an alpha scintillation flask and calculate the ^{226}Ra concentration from the ^{222}Rn grow-in. For water with low specific activity, larger volumes (5-10 L) may be de-gassed onto a cold (2-30°C) activated charcoal radon trap, and the trapped radon then released by warming to 80°C or more into a small alpha scintillation (Lucas-type) flask.

Total (Gross) Alpha and Beta Radioactivity

Evaporate a water sample onto a planchet suitable for use in a gas flow-through proportional counter. Dried solids should not exceed 5 mg/sq cm for alpha counting and not exceed 10 mg sq/cm for beta counting. If one sample is to be used for both alpha and beta, then 5 mg sq/cm should not be exceeded. The precipitated alpha and beta radioactivity on the planchet is measured in a gas flow-through proportional counter. (See Reference 7.23.)

222-Radon Flux at Landfill or Pond Surface

Gaseous diffusion and/or convection across the surface interface can transport ^{222}Rn formed in the decay of ^{226}Ra.

^{222}Rn flux is measured using canisters containing activated charcoal placed at selected locations on the surface of a landfill or pond and at selected locations adjacent to the fill or pond. The canisters are left in place, usually under a protective housing similar to an empty inverted tin can, opened at one end, for several hours to several days, depending on the specific ^{222}Rn flux across the interface. Upon completion of the recorded measurement period, the canisters are put into thick plastic bags, the bags are sealed and stored for several hours to allow grow-in of the short-lived gamma-emitting radon daughter products, ^{224}Pb and ^{214}Bi. The accumulated gamma ray activity in the canister is measured directly using a calibrated gamma ray detector such as a NaI:T1 crystal. (See Reference 7.24.)

APPENDIX D

APPLICATION OF THE EPA EXTRACTION PROCEDURE AND RADIOACTIVITY MEASUREMENTS TO COAL-FIRED UTILITY WASTES

FULL-SCALE FIELD EVALUATION OF WASTE DISPOSAL FROM COAL-FIRED ELECTRIC GENERATING PLANTS

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ABSTRACT

This report presents the results of radioactivity measurements and trace metal concentrations in extracts obtained using the EPA-Extraction Procedure (EP) for wastes obtained from coal-fired utility plants. Twenty-three waste samples (fly ash and flue gas desulfurization [FGD) wastes) were subjected to the extraction procedure. Thirty-four samples (fly ash, bottom ash, FGD wastes and boiler slag) were analyzed for concentrations of radium-226 using gamma ray spectroscopy. Several samples were also analyzed for radium-228, thorium-228, potassium-40, uranium-238, total uranium and for fractional radon emanation.

In no case did the concentrations of the eight metals determined in the EP extracts of these wastes exceed the one hundred times Interim Primary Drinking Water Standards criteria (100 x) as published in the Federal Register of May 19, 1980. The range of concentrations observed in all the extracts relative to the Interim Primary Drinking Water Standards were As <0.04-8.2x, Ba <0.1-0.7x, Cd <0.2-19x, Cr <0.2-19x, Pb <0.1-0.7x, Hg <1x, Se <0.2-34x and Ag <0.02 times the standard. For none of the samples analyzed did the ^{226}Ra concentration exceed the proposed limit of 5 pCi/g as given in the Federal Register of Dec 18, 1978. The range observed for ^{226}Ra activity for the fly ash samples was 2.0-4.7 ; the bottom ash samples 1.7 - 4.5; boiler slag samples 2.3 to 3.5; and the FGD samples <0.9-3.1 pCi/g.

Concentrations of ^{228}Ra, ^{228}Th, ^{40}K, and ^{238}U in the analyzed ash samples ranged from 2.4-3.6, 2.4-3.0, 8.4 to 28.5 and 4.1-4.5 pCi/g, respectively.

Fractional radon emanation measurements on four fly ash samples and two FGD samples showed no emanation within the accuracy of the measurements, suggesting that the radium is not concentrated on the surface of the ash particles.

TABLE OF CONTENTS

Page (D-)

Abstract ii

List of Tables iii

List of Figures iv

Abbreviations v

Acknowledgements vi

1. Introduction 1

2. Experimental Procedures 2

   2.1 Waste Samples 2

   2.2 Extraction Procedure 2

   2.3 Metals Analysis Methods 5

   2.4 Radioactivity Analysis Methods 5

   2.5 Quality Control Procedures 8

3. Results and Discussion 10

   3.1 Extraction Procedure 10

   3.2 Radioactivity Measurement 13

References 23

Appendix A - Extraction Procedure Measurements Supplemental Data 25

Appendix B - Radioactivity Measurements Supplemental Data 29

LIST OF TABLES

Table No.		Page (D-)
1.	Waste Samples Studied	3
2.	Summary of Metal Analysis Methods	6
3.	Summary of Extraction Procedure Data for FGC Waste Samples from Various Coal Fired Power Plants	11
4.	Range of Concentrations of Metals in EP Extracts of Fly Ash and FGD Samples Compared to Interim Primary Drinking Water Standards	12
5.	Radium-226 Concentrations in Sealed Samples of Fly Ash Bottom Ash, Boiler Slag and FGD Wastes	15
6.	Typical Gamma Ray Energy Spectrum Observed for Fly Ash and Bottom Ash Samples	17
7.	Concentrations of Several Naturally Occurring Radioactive Nuclides in Samples of Fly Ash, Combined Ash and FGD Wastes	20
8.	Fractional Radon-222 Emanation(%) in Ash and FGD Waste Samples	21
A-1	Summary of Quality Control Experiments: Data for Blanks	26
A-2	Calculation of Detection Limits	27
A-3	Replicate Extraction Data	28
B-1	Radium-226 Concentrations based on 0.352 MeV and 0.609 MeV gamma rays	30

LIST OF FIGURES

1.	EPA-EP Apparatus	4
B-1	Gamma Ray Energy Versus Channel Number for Ge(Li) Gamma Ray Detector	33
B-2	Absolute Counting Efficiency as A Function of the Gamma Ray Energy for a Fixed Sample/Detector Geometry	34

ABBREVIATIONS

EP - EPA Extraction Procedure

FGD - Flue Gas Desulfurization

ml - milliliter

N- normal concentration (equivalents/1)

mm - millimeter

μm - micrometer

nm - nanometer

MeV - Million-electron volt(s)

μg/1 - micrograms per liter or parts per billion (ppb)

mg/1 - milligrams per liter or parts per million (ppm)

pCi/g - picocuries per gram (10^{-12} Curies/g)

γ - gamma ray

RSD - relative standard deviation

g- grams

cm - centimeter

ACKNOWLEDGEMENTS

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1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) as part of its harzardous waste and consolidated permit regulations under the Resource Conservation and Recovery Act (RCRA) published in the May 19, 1980 Federal Register (1) the EPA Extraction Procedure (EP) which can be used to determine if a waste exhibits the characteristic described as EP-toxicity. Under this regulation a waste exhibits this characterisitc if the extract obtained from a sample of waste using the described procedure contains concentrations of one or more of eight designated metals or of one or more of six designated organics equal to or higher than prescribed limits. In addition, the EPA published proposed regulations in the December 18, 1978 Federal Register which would define the levels of radium-226 in a waste at which it may be considered as having radioactive hazard potential under RCRA (2). Arthur D. Little, Inc. under EPA contract 68-02-3167, is conducting a study to evaluate the overall environmental effects of land disposal of utility waste (fly ash, bottom ash, and flue gas desulfurization wastes) produced by full scale coal fired utility plants. As part of this study grab samples of waste from eighteen plants have been subjected to the EPA-Extraction Procedure and radioactivity tests to obtain preliminary data on these wastes (3). This data from the large number of plants is expected to be useful in providing preliminary indications of the relative impact of wastes from this industry.

2. EXPERIMENTAL PROCEDURES

2.1 Waste Samples

Most of the waste samples studied were obtained during site visits to the plants by members of the Arthur D. Little, Inc. project team, although in a limited number of cases, samples were provided by utility personnel. All samples were single grab samples of a particular waste stream, and thus the experimental results are not necessarily representative of the average wastes produced by a plant over an extended period of time.

Samples were collected in cleaned glass or plastic containers. The samples collected included: twenty fly ash samples (from sixteen plants); seven bottom ash samples (from seven plants); four flue gas desulfurization (FGD) waste samples (from four plants); two boiler slag samples (from two plants) and two combined fly and bottom ash samples (from two plants). A summary of the waste materials studied and the type of tests performed on them is provided in Table 1. The names of the plants and the location of the utility are not identified pursuant to EPA's desire to maintain the generic nature of these analytical efforts.

The EPA-EP procedure was performed only on the fly ash and FGD materials. Radium-226 measurements were performed on most of the samples. Other radioactivity measurements (radium-228, thorium-228, potassium-40 uranium-238, total uranium and fractional radon emanation) were performed on three fly ash samples from three plants, two FGD samples from two plants and one combined ash sample.

2.2 Extraction Procedure (EP)

Samples of fly ash and FGD waste were subjected to the EPA-EP as described in the Federal Register, May 19, 1980 (1). All of the samples had small particle sizes such that the samples passed the 9.5 mm sieve requirement and thus were not subjected to any cutting or grinding.

A schematic of the EP setup is given in Figure 1. The extraction chamber is a one gallon glass jar fitted with a plexiglass cover having various ports for the stirrer, pH electrodes, and a tube for the addition of acetic acid. The pH controller (Horizon Ecology Model 5997-20) was used to control a peristaltic pump (Cole Parmer Masterflex) for the addition of 0.5N acetic acid. The pH control points were set so that acid addition was initiated at pH $\geq$ 5.2 and stopped at pH $\leq$ 5.0. The addition rate of the acetic acid using the pump was approximately 1 mL/min. The acid reservoir was filled with the maximum amount of acid allowed under the EP procedure (e.g., 400 mL of 0.5 N acetic acid for 100 g of solid) so that an excess could not be added even when the controller kept the pump running. Stirring was set at a rate sufficient to suspend all the solid material. The extraction process was carried out for a 24 hour period as specified in the regulations (1).

TABLE 1

Waste Samples Studied

Utility Code	Sample Codes	Type of Sample	Date Sampled	Analyses	
				EP	Radio-activity
1	EP-1(a),R-1(a)	Fly Ash	July 16, 1980	X	X
1	EP-1(b),R-1(b)	Fly Ash	July 16, 1980	X	X
1	EP-1(c),R-1(c)	Fly Ash	July 16, 1980	X	X
2	EP-2(a),R-2(a)	Fly Ash	July 30, 1980	X	X
2	EP-2(b),R-2(b)	Fly Ash	July 30, 1980	X	X
2	R-2	Bottom Ash	July 30, 1980		X
3	R-3	Bottom Ash	Sept 19, 1980		X
3	EP-3,R-3	Fly Ash	Sept 19, 1980	X	X
4	EP-4(a),R-4(a)	Fly Ash	Sept 5, 1980	X	X
4	R-4(b)	Boiler Slag	Sept 5, 1980		X
5	EP-5(a),R-5(a)	Fly Ash	July 30, 1980	X	X
5	EP-5(b),R-5(b)	Fly Ash	July 30, 1980	X	X
5	R-5(c)	Bottom Ash	July 30, 1980		X
6	EP-6(a),R-6(a)	Fly Ash	Aug 26, 1980	X	X
6	R-6(b)	Boiler Slag	Aug 26, 1980		X
7	EP-7(a),R-7(a)	Fly Ash	Sept 4, 1980	X	X
7	R-7(b)	Bottom Ash	Sept 4, 1980		X
8	EP-8(a),R-8(a)	Fly Ash	Sept 5, 1980	X	X
8	EP-8(b),R-8(b)	FGD	Sept 5, 1980	X	X
9	EP-9(a),R-9(a)	Fly Ash	Sept 11, 1980	X	X
9	R-9(b)	Combined Fly Ash/ Bottom Ash	Sept 11, 1980		X
10	EP-10(a),R-10(a)	Fly Ash	Sept 17, 1980	X	X
10	R-10(b)	Bottom Ash	Sept 17, 1980		X
11	EP-11(a),R-11(d)	Fly Ash	Sept 18, 1980	X	X
11	R-11(b)	Bottom Ash	Sept 18, 1980		X
12	EP-12(a),R-12(a)	Fly Ash	Oct 21, 1980	X	X
12	R-12(b)	Bottom Ash	Oct 21, 1980		X
13	EP-13(a),R-13(a)	Fly Ash	Oct 27, 1980	X	X
13	EP-13(b),R-13(b)	FGD	Oct 27, 1980	X	X
14	EP-14,R-14	Fly Ash	Oct 21, 1980	X	X
15	EP-15(a),R-15(a)	Fly Ash	Sept 11, 1980	X	X
15	R-15(b)	Combined Fly Ash/ Bottom Ash	Sept 11, 1980		X
16	EP-16,R-16	FGD/Fly Ash Mixture	Aug 26, 1980	X	X
17	EP-17	Fly Ash	Jan 20, 1981	X	
18	R-18	FGD	Apr 2, 1981		X

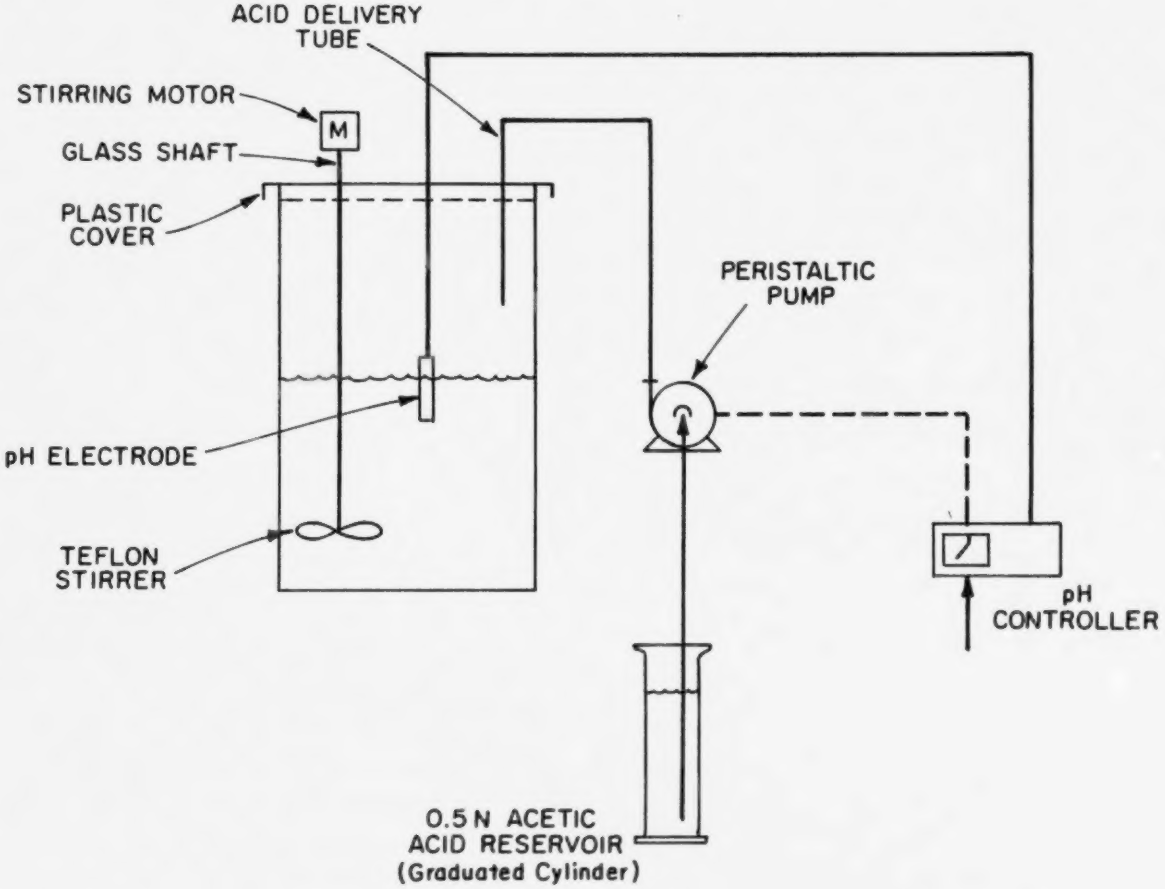
ACID DELIVERY TUBE
STIRRING MOTOR
M
GLASS SHAFT
PLASTIC COVER
PERISTALTIC PUMP
pH ELECTRODE
TEFLON STIRRER
pH CONTROLLER
0.5 N ACETIC ACID RESERVOIR (Graduated Cylinder)

FIGURE 1. EPA-EP APPARATUS.

Dry solid samples were used as received. Approximately 100 g (weighed accurately) of sample was used. Slurry samples were separated using a teflon coated pressure filtration apparatus (Millipore model YT30142HW) and 0.45 μm polycarbonate filters (Millipore HAWP). Pure tank nitrogen was used as the source of pressure. The liquid portion of the filtered slurry was retained and the solid portion extracted. After extraction the slurry was separated using the pressure filtration apparatus. The extract and liquid portion were recombined as specified in the procedure. This mixture was stabilized for metal analysis by addition of 5 mL of concentrated reagent-grade nitric acid. The extracts were analyzed only for the metal species listed in the EP procedure since occurrence of the organic species listed in the prescribed protocol in these utility wastes was considered to be extremely unlikely. More complete details of the extraction procedure can be found in References 1 and 5.

2.3 Metals Analysis

A summary of the analysis methods used to measure the eight trace metals (Ag, As, Se, Hg, Cr, Cd, Pb, Ba) is given in Table 2. Arsenic and selenium were measured using the gaseous hydride evolution methods. For arsenic a 10 mL volume of sample was introduced into the hydride generating apparatus and then 5 mL of HCl and 2 mL of 25% aqueous potassium iodide solution were added. The hydride was generated by injection of 2.5 mL of a solution of 5% sodium borohydride in 10% sodium hydroxide solution. Selenium was analyzed similarly to arsenic in that 10 mL volume of sample was introduced into the apparatus followed by 10 mL of HCl and the hydride generated by injection of 2.5 mL of 4% sodium borohydride in 10% sodium hydroxide solution. Mercury was analyzed using the cold vapor technique as described in EPA method 245.1 (5). All of the other elements (silver, chromium, lead, cadmium, barium) were analyzed using graphite furnace atomic absorption techniques using the operating conditions recommended by the instrument manufacturer and guidelines given in the EPA Methods (6). The graphite furnace atomic absorption measurements were carried out on an Instrumentation Laboratories 551 AA Spectrophotometer. Hydride evolution and the mercury cold-vapor analysis methods were performed on a Perkin Elmer 503 AA spectrometer.

2.4 Radioactivity Analysis Methods

The analysis method used for measurement of radium-226 (^{226}Ra) in the samples and the limited studies performed for radon-222 (^{222}Rn) as well as determination of other radioactive species in the samples was gamma-ray spectroscopy (7). Measurements were made of the 0.352 MeV gamma ray of lead-214 (^{214}Pb) and the 0.609 MeV and 1.12 MeV gamma rays of bismuth-214 (^{214}Bi) which are daughter products in the decay of ^{222}Rn which itself is produced by decay of ^{226}Ra. The measurement apparatus consisted of a calibrated high-resolution 10% Ge (Li) detector, (Ortec Inc., Oak Ridge, TN,) a signal amplifier (Ortec 560) and 1024-channel pulse analyzer (Tracor Northern Scientific NS-700).

TABLE 2

Summary of Metal Analysis Methods

Element	Method	Wavelength (nm)	Conditions (°C) Dry	Conditions (°C) Pyrolyze	Conditions (°C) Atomize	Calibration Range (ppb)
As	Hydride Evolution	194	-	-	-	0-20
Se	Hydride Evolution	196.5	-	-	-	0-30
Hg	Cold Vapor	253.7	-	-	-	0-6
Ag	Graphite Furnace Atomic Absorption	328.1	150	300	1800	0-20
Ba	Graphite Furnace Atomic Absorption	553.5	150	1100	2250	0-200
Cd	Graphite Furnace Atomic Absorption	228.8	150	2000	-	0-20
Cr	Graphite Furnace Atomic Absorption	357.7	150	900	1850	0-50
Pb	Graphite Furnace Atomic Absorption	383.3	150	600	1900	0-50

Samples of fly ash, bottom ash, boiler slag and FGD waste (37 to 352 g) were dried at 86°C for 22 hours and sealed in flat metal cans (similar to the familiar tuna fish food can) of two different sizes depending on sample size (8.2 cm diameter x 4.3 cm deep and 6.7 cm diameter x 2.3 cm deep). The can tops were sealed using a crimping can sealer and bees-wax was added around the seals of the can to insure retention of radon gas. The end of the can was placed co-axially with the flat end of the the Ge(Li) gamma ray detector housing. The complete system of sample and detector was shielded with lead bricks to give a minimum of stray radiation background. For measurement of ^{226}Ra, the samples contained in the radon-tight cans were stored for 30 days to allow re-equilibration of the natural ^{222}Rn/^{226}Ra ratio which was likely to have been perturbed by the sample preparation steps if ^{222}Rn loss occurred.

Gamma ray energies were scanned from 0 to about 2 MeV and other emitting nuclides were identified by the characteristic energies of their emitted gamma-rays. (Calibration plots of gamma ray energy vs channel number and of the detector counting efficiency vs gamma ray energy are included in Appendix B). The gamma ray counting time varied between 9,000 and 429,000 seconds (3 hrs to 5 days) but generally was held in the range of 20,000 to 60,000 seconds.

The activities of ^{214}Pb and ^{214}Bi produced by decay of ^{222}Rn (half life of ^{222}Rn is 3.8 days) are equal considering the half lifes involved and thus these are a measure of the ^{222}Rn content of the sample which in turn is a measure of the ^{226}Ra content. The fractional radon emanation (%) is defined as:

$$\left(\frac{[^{222}\mathrm{Rn}]_{\ 30\ \mathrm{days}} - [^{222}\mathrm{Rn}]_{\ 0\ \mathrm{days}}}{[^{222}\mathrm{Rn}]_{\ 30\ \mathrm{days}}} \right) \times 100$$

Thus measurements of the activity of ^{214}Pb and ^{214}Bi after 30 days and after evacuation of the 30 day old sealed sample (0-days) gives a quantitative measure of the fractional radon emanation from the sample. The 0-day samples were prepared from the 30 day samples by piercing holes in the cans and placing the can in a vacuum chamber. The sample was evacuated and refilled with nitrogen twice, then the short lived γ-emitting daughters were allowed to decay for 3 hours prior to making the measurement of the non-emanated radon.

The activities of ^{228}Ra, ^{228}Th and ^{238}U in the samples were estimated from measurements of the activity of their decay products. Thus, ^{228}Ra activity was determined as ^{228}Ac (0.91 and 0.969 MeV gamma rays), ^{228}Th determined as ^{208}Tl (0.585 MeV gamma ray), ^{238}U as ^{235}U (0.186 MeV gamma minus ^{226}Ra contribution) and total U as ^{235}U (0.186 MeV gamma ray).

2.5 Quality Control Procedures

A number of quality control tests and checks were performed during the course of the extraction procedure. These tests were designed to monitor possible sources of contamination in the various steps of the extraction and to provide an indication of reproducibility of the overall extraction results. A total system blank was run at least once each week. This consisted of distilled water acidified to pH 5.0 with acetic acid which was carried as a sample through the complete extraction and filtration procedure. In addition, contamination arising from the extract storage bottles (bottle blank) and the filters (filter blanks) were also monitored. The results of these "blank" tests are summarized in Table A-1, Appendix A.

Duplicate extractions were performed on three materials to check repeatability of the overall extraction procedure. These results are shown in Table A-3, Appendix A.

All samples were subjected to an initial "survey" measurement for each analyte. Those samples which contained a detectable amount of analyte were subjected to further quantitation using the method of standard additions (8). Samples were spiked to contain an additional 50%, 100% and 150% of the analyte concentration determined during initial survey analysis.

The reproducibility of the analytical measurements was estimated from several replicate measurements of standard solutions. Detection limits, reported in Table A-3, Appendix A were taken as two times the standard deviation of the replicate standard measurements and assume that absolute imprecision at the blank level is the same as that at the measured standard level. It should be noted that the detectabilities of interest in these experiments range in the area of the proposed primary drinking water criteria (9).

The gamma ray spectrometer was calibrated using four National Bureau of Standards (NBS) reference standard sealed glass vials each containing 0.202 μCi of ^{226}Ra placed in a sand matrix contained in a 8.5 cm diameter x 4.3 cm deep metal can. In addition, comparative measurements of a fly ash sample (R-1) by this laboratory and by the Environmental Measurement Laboratory of the Department of Energy (New York City, NY) confirmed the calibration (10). The NBS standard yielded values of 115×10^{-6} counts per second per pCi of ^{226}Ra using the 0.352 MeV γ-ray. This compares well with the independent laboratory measurement of 110×10^{-6} counts per second per pCi of ^{226}Ra at the same energy for a sample of R-1. The respective values for the 0.609 MeV γ-ray were 67.2×10^{-6} and 67.7×10^{-6} counts per second per pCi of ^{226}Ra.

Background counts were monitored weekly at the respective energies used for quantitation and if required appropriate corrections were made.

Precision of the ^{226}Ra analysis was determined by replicate measurement of three samples as well as measurements made using both the 0.352 MeV gamma and the 0.609 MeV gamma (11). These data are summarized in Table B-1, Appendix B.

The results of all the quality control procedures are summarized in the experimental results and discussion section and in Appendices A and B.

3. RESULTS AND DISCUSSIONS

3.1 Extraction Procedure

The results obtained for the analysis of extracts of 20 fly ash samples from 16 plants and three flue gas desulfurization (FGD) waste samples from three plants are summarized in Table 3. Because the single "grab" samples obtained in this study could not be considered representative of the particular plant or facility, the samples were given coded identification numbers. The sum total of the results showing the range and distribution for a number of plants may be taken to give preliminary indications of the general properties and trends of these wastes for the industry.

The range of concentrations observed for these samples and their relationship to the EPA Interim Primary Drinking Water standards are summarized in Table 4. Neither silver nor mercury was detected in any of the fly ash or FGD extracts and very few samples showed any detectable levels of lead. Detectable levels of the other metals were observed but none of them exceeded the proposed RCRA EP Criteria of 100 times Interim Primary Drinking Water Standards as published in the May 19, 1980 Federal Register (1). The FGD samples tended to fall in the lower end of the concentration range found for fly ash samples. The ranges of concentrations observed for these metals in the EP extracts fall within those reported by other studies on utility wastes (12,13).

The quality control data, given in Appendix A, include the data obtained for the various blanks (Table A-1) and the relative standard deviation values obtained for standards which were used to determine detection levels (Table A-2). The data on the various blanks indicate that barium contamination from the filters occurred. Since the level of barium contamination however was about 0.1 times the proposed Primary Drinking Water Criteria (1,000 ppb), no corrective action in the test procedure was taken. However, the detection limit and confidence level of the barium data was adjusted upward to include this contribution of barium by the filters. No contamination from other metals analyzed was observed in any of the steps in the procedure.

The method of standard addition which was used to quantify all samples where detectable levels were observed during preliminary measurements, showed widely varying matrix effects for some samples during measurements of barium and lead. For barium, the slope of the calibration/response line for the standard addition plots varied from 0.5 to 1.5 (with an average of 0.85) times the slope of the independent calibration plots using aqueous standards. For lead, the corresponding ratio of slopes was 0.7 to 2.5 (average 0.89). Other elements (As, Se, Cd) showed only minor matrix effects for the samples studied. The range for the ratio of slopes for these elements was 0.81-1.02 (average 0.92), 0.78-0.94 (average 0.86), and 0.74-1.2 (average 0.94) for As, Se and Cd, respectively. No standard addition was performed for the mercury and silver analyses.

TABLE 3

Summary of Extraction Procedure Data for FGC Waste Samples
From Various Coal Fired Power Plants

Sample[a]	Concentration in Extract[b]							
	As (µg/l)	Cd (µg/l)	Cr (µg/l)	Pb (µg/l)	Hg (µg/l)	Se (µg/l)	Ag (µg/l)	Ba (mg/l)
Fly Ash Samples:								
EP-1(a)	39±10	10±3	23±8	<6	<2	7±2	<1	<0.16
EP-1(b)	63±10	5±3	<8	<3	<2	8±2	<1	0.36±0.16
EP-1(c)[c]	98±20	16±3	12	<3	<2	52±7	<1	0.51±0.16
EP-2(a)[c]	<5	<2	240±37	<3	<2	17±3	<1	1.2±0.16
EP-2(b)	<5	11±3	430±73	<3	<2	<5	<1	0.4±0.1
EP-3(a)	<2	6±2	19±13	<4	<2	10±2	<1	0.34±0.15
EP-4(a)	<2	63±5	<9	<5	<2	34±9	<1	<0.11
EP-5(a)	<6	6±2	<57	<3	<2	21±3	<1	<0.15
EP-5(b)	<6	<2	445±37	<4	<2	25±3	<1	0.17±0.10
EP-6(a)	<24	90±32	320±73	<36	<2	13±2	<1	<0.3
EP-7(a)	<24	193±32	110±37	<3	<2	5±2	<1	-
EP-8(a)	30±10	135±32	56±15	<3	<2	59±7	<1	0.3±0.1
EP-9(a)	410±41	16±2	<13	<4	<2	340±43	<1	0.4±0.10
EP-10(a)	14±2	26±5	930±558	<5	<2	160±43	<1	0.30±0.10
EP-11(a)	19±2	19±4	480±280	23±5	<2	60±17	<1	0.7±0.3
EP-12(a)	310±41	4±2	<11	<5	<2	<2	<1	0.33±0.15
EP-13(a)	5±2	5±2	<11	24	<2	<2	<1	<0.1
EP-14	200±41	8±2	<8	<3	<2	73±17	<1	0.20±0.10
EP-15(a)	340±41	30±4	<19	10±5	<2	83±17	<1	0.28±0.10
EP-17[c]	6±2	<2	14±3	<3	<2	9±2	<1	<0.5
FGD Samples:								
EP-8 (b)	<2	<2	<11	<5	<2	9±2	<1	0.16±0.11
EP-13(b)	65±8	<2	<11	-	<2	49±17	<1	<0.15
EP 16	<5	20±3	26±15	<5	<2	8±2	<1	0.23±0.11

[a] Samples are listed according to a code given to the various plants

[b] Error limits as well as detection limits were calculated using twice the standard deviation of replicate standard solutions and dilution factors (see text).

[c] Performed in duplicate. Value reported is highest of two observed. See Table A-3.

TABLE 4

Range of Concentrations of Metals in EP Extracts of Fly Ash and FGD Samples Compared to Interim Primary Drinking Water Standards

Metal	Overall Range Observed(A)	Interim Primary Drinking Water Standards(B)	Ratio of A to B
As	<2 - 410 μg/1	50 μg/1	<0.04 to 8.2
Ba	<0.1-0.7 mg/1	1.0 mg/1	<0.1 to 0.7
Cd	<2 - 193 μg/1	10 μg/1	<0.2 to 19.3
Cr	<8 - 930 μg/1	50 μg/1[a]	<0.16 to 18.6[b]
Pb	<3 - <36 μg/1	50 μg/1	<0.06 to 0.72
Hg	<2 μg/1	2 μg/1	<1
Se	<2 - 340 μg/1	10 μg/1	<0.2 to 34
Ag	<1 μg/1	50 μg/1	<0.02

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[a] The Federal Register of Thursday Oct. 30, 1980 pp 72024-41 contained an amendment to the chromium criteria for the EP revising it from total chromium to Cr(VI).

[b] Since total chromium values are measured by the AA analysis method, these are upper limits for the Cr(VI) values.

3.2 Radioactivity Measurements

Naturally occurring uranium (U) and thorium (Th), the isotopes of which are all radioactive, initiate a long decay series of radioactive nuclides. Among these nuclides are ^{226}Ra (from the U series) and ^{228}Ra (from the Th series). Typical concentrations of ^{226}Ra and ^{228}Ra in sedimentary rocks (assuming equilibrium with parent nuclides) are 1 pCi/g and 0.4 pCi/g, respectively (14).

Coals also contain concentrations of these radionuclides. Following combustion of coal, the naturally occurring U, Th, ^{226}Ra and ^{228}Ra are likely to be found in the non-volatile combustion products (e.g., bottom and fly ash). As a result of this ashing process the concentration of these species in the ash will be increased relative to those in the coal since the combustion products of these species are not likely to be sufficiently volatile to be lost in the gaseous products. Such an increase in concentration for other elements has been reported. Three to ten-fold increases in concentrations of these species in ash by-products of a limited number of coals were noted and in some cases small particle fractions of fly ash had concentrations greater than 5 pCi/g of ^{226}Ra (15).

Another study which investigated a large number of ash samples (from 55 different coal sources) reported that about 36% of the national coal reserves were expected to produce levels of ^{226}Ra in excess of 5 pCi/g (16). It should be noted that these investigators determined the ^{226}Ra concentrations by extrapolation from the ^{238}U concentration (parent of ^{226}Ra) and by assuming that the two nuclides were in radioactive "secular equilibrium." This assumption may not be accurate since the long half-life of ^{226}Ra (1,600 years) and the period in excess of 10^9 years required for decay from ^{238}U to produce measurable amounts of ^{226}Ra coupled with the very different geochemistry of radium (an alkaline earth) from that of uranium (a member of the actinide series) may well allow ample opportunity for dislocation (e.g., leaching, recrystalization) of ^{226}Ra from the host rock and coal minerals.

The EPA in the Federal Register of December 18, 1978, has listed a level of 5 pCi/g of ^{226}Ra in the proposed guidelines for evaluating radioactivity in solid wastes. In summary these proposed guidelines state that a solid waste (as defined in the proposed guidelines) would be declared a hazardous waste if: 1) it is not a "source material," "special nuclear material," or "by-product material" as defined by the Atomic Energy Act of 1954 and if, 2) a representative sample of the waste has either an average concentration of ^{226}Ra exceeding 5 pCi/g in a solid or 50 pCi/liter of ^{226}Ra and ^{228}Ra for liquids or a total ^{226}Ra activity equal to or exeeding 10 μCi for any single discrete source.

Other considerations with regard to the possible effects of radium nuclides in utility wastes are: 1) the relative availability of the ^{226}Ra for leaching from the ash and subsequent migration into groundwaters and; 2) the production of ^{222}Rn gas which is often associated with elevated levels of ^{226}Ra. Radon-222, the radioactive noble gas daughter product of ^{226}Ra itself decays to produce a series of non-gaseous alpha-emitting nuclides of polonium (Po), and beta-emitting nuclides of bismuth (Bi) and lead (Pb).

For some volatile elements (e.g., As, Se), volatilization-condensation processes in the combustion process have been invoked to account for the relatively higher concentrations of such species on the finer fractions (small particles with high surface areas) of the ash. While such processes are speculative for the heavy nuclides, they cannot necessarily be ruled out (1). Thus, higher concentrations of species at the surface of the particles would lead to greater leachability of these species and for ^{222}Rn (a product of the ^{226}Ra decay), greater opportunity for leaving the ash particle as a gas. The process of separation of the radon from the radon-bearing solids is termed "radon emanation." A study of the radon emanation quantity would aid in determining whether the ^{226}Ra is concentrated on the surface of the particle or distributed within it and would, in addition, provide additional information of possible gas emanation problems. A previous study of some 21 coal fly ash and related samples has suggested a value of about 40% for the radon emanation (19). However, the calculations upon which this value was based had a fundamental error in assuming that the 0.185 MeV γ-ray of ^{235}U causes a <20% error in the determination of Ra-226, whereas in reality the values may nearly be 100% error*.

The data obtained in this study for the ^{226}Ra content of 20 fly ash, eight bottom ash, four FGD, two combined fly and bottom ash and two boiler slag samples are shown in Table 5. The ^{226}Ra activity in pCi/g ranged from 1.8 to 4.7 for the fly ash samples, and 1.7 to 4.5 for the bottom ash. The combined bottom and fly ash and boiler slag samples were similarly within these ranges. The three FGD samples had a ^{226}Ra activity in the range of 0.9 to 3.1 pCi/g. A summary of the sample size, count time and comparison of the data obtained using the intensities of the 0.352 MeV gamma ray versus the 0.609 MeV gamma ray are given in Table B-1 in Appendix B. Measurement of both gamma rays provides greater confidence in the low level activities observed. In general, relatively good agreement was observed for the replicates as well as the values obtained using the two different gamma rays.

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*Both ^{235}U and ^{226}Ra emit gamma rays in the 185±1 KeV energy range. The total counts observed at this energy can be nearly 50% due to ^{226}Ra and 50% due to ^{235}U. Thus, if one assumes no contribution from ^{235}U, the calculated ^{226}Ra activity based on the measured counts at this energy would be twice the activity of only the ^{226}Ra in the sample.

TABLE 5

Radium-226 Concentrations in Sealed Samples of Fly Ash, Bottom Ash, Boiler Slag and FGD Wastes

Sample[a]	^{226}Ra Concentrations (pCi/g)[b]
Fly Ash:	
R-1(a)	3.5±0.3
R-1(b)	4.2±0.4
R-1(c)	4.3±0.3
R-1(d)	4.3±0.3
R-2(a)	2.9±0.1
R-2(b)	3.9±0.5
R-3(a)	3.4±0.1
R-4(a)	4.7±0.5
R-5(a)	3.4±0.3
R-5(b)	3.1±0.1
R-6(a)	4.7±0.3
R-7(a)	4.1±0.2
R-8(a)	4.1±0.1
R-9(a)	3.9±0.5
R-10(a)	2.9±0.3
R-11(a)	3.8±0.3
R-12(c)	4.0±0.3
R-13(a)	2.0±0.2
R-14	4.5±0.3
R-15(a)	3.8±0.5
Bottom Ash:	
R-2 (c)	1.7±0.2
R-3 (b)	1.9±0.2
R-5 (c)	4.1±0.6
R-7 (b)	3.2±0.3
R-10(b)	2.8±0.5
R-11(b)	1.9±0.1
R-12(a)	4.2±0.5
R-12(b)	4.5±0.2
Boiler Slag:	
R-4 (b)	2.3±0.4
R-6 (b)	3.5±0.1
Combined (Fly Ash - Bottom Ash)	
R-9 (b)	3.6±0.5
R-15(b)	3.1±0.2
FGD (with/without ash)	
R-8 (b)	0.9±0.6
R-13(b)	<1.3
R-16	3.1±0.2
R-18	0.3±0.1

[a] Samples are listed according to code given to the various plants

[b] Gamma Ray Spectroscopy - Errors quoted are one standard deviation calculated based on procedures given in Reference 11. See Table B-1 for additional data.

Table 6 provides a listing of the gamma ray energy spectrum observed for most of the fly ash and bottom ash samples. Included in the table are the emitting nuclide and relative peak intensity in the spectrum of a representative sample. Essentially all of the photopeaks observed may be related to the naturally occurring radioactive decay series of ^{235}U, ^{238}U, ^{232}Th and ^{40}K.

Table 7 provides data on nuclide concentrations (pCi/g) of ^{228}Ra (using the ^{228}Ac product), ^{228}Th (using ^{208}Tl product), ^{40}K, ^{238}U (using ^{235}U minus contribution from ^{226}Ra at 0.186 MeV) and total uranium in ppm. Three fly ash, one bottom ash and two FGD samples were analyzed in these experiments. Data for fractional radon-222 emanation in percent are given in Table 8.

The three total uranium values (range of 12.3 to 13.6 ppm) are very similar to that reported by other investigators for a Bull Run sample of fly ash (20). The ^{40}K data are in agreement with the generally observed total concentration of potassium in these samples. Recalling that 7.10 pCi/g of ^{40}K represents 1 ppm and that 1 ppm of ^{40}K represents 8,400 ppm of total K, the total K content observed for the fly ash and bottom ash samples range from 9,900 to 32,000 ppm (0.99 to 3.2%) and 6,600 ppm (0.66) for one FGD sample. These values are in the range previously reported for these types of samples (21).

Radium-228 concentrations in the fly ash and bottom ash samples were in the 2.6 to 3.6 pCi/g range. Thorium-228 concentrations were in the 2.4 to 3.0 pCi/g for the ash samples and 0.9 to 1.9 for the two FGD samples studied. It should be noted that one of the samples of FGD material studied contained ash [sample R-16] while the other did not. Uranium-238 levels were in the 4.1 to 4.5 pCi/g range for the ash samples studied.

Fractional emanation measurements for all the samples studied showed no emanation within the accuracy of the measurements (Negative values in the table indicate that the measured 0-day sample value exceeded the measured 30-day sample value).

The low fractional emanation for the ash particles suggests that the radium is not preferentially concentrated at the surface of the particle. Assuming that the ^{226}Ra (radioactive parent of radon-222), is uniformly distributed throughout the fly ash particles; emanation of radon from an average 30 μm diameter particle would be less than 1% of the radon-222 (16,22). This is because the recoil associated with the emission of a 4.6 to 4.8 MeV alpha particle, which occurs when ^{222}Rn is formed, causes the ^{222}Rn atom to travel about 0.06 μm. By contrast, radon emanation from 1 μm size particles would be expected to be 5 to 10%. The observed radon emanation data suggests that preferential concentration of ^{226}Ra on surfaces of smaller particles does not occur during the coal combustion process and that it is distributed throughout the particles.

TABLE 6

TYPICAL GAMMA RAY ENERGY SPECTRUM OBSERVED FOR FLY ASH AND BOTTOM ASH SAMPLES[a]

Gamma ray[c] Energy (MeV)	Emitting Nuclide	Gamma Abundance (% gamma/decay)	Relative Peak Intensity[b] Observed In Spectra
0.08	^{214}Pb x-rays, etc.	---	M
0.09	^{214}Pb x-rays, etc.	---	M
0.14	^{235}U	12 %	S
0.185	^{235}U	55 %	i
0.185	^{226}Ra	3 %	---[d]
0.21	^{228}Ac	3.5%	S
0.21	^{239}Np	3 %	---
0.21	^{227}Th	<1 %	---
0.24	^{214}Pb	4 %	M
0.24	^{224}Ra	4 %	---
0.24	^{212}Pb	47 %	---
0.24	^{227}Th	15 %	---
0.27	^{219}Rn	9 %	S
0.27	^{223}Ra	10 %	---
0.30	^{214}Pb	19 %	M
0.30	^{212}Pb	3 %	---
0.30	^{231}Pa	6 %	---
0.30	^{227}Th	8 %	---
0.34	^{228}Ac	15 %	i
0.34	^{223}Ra	6 %	---
0.352	^{214}Pb	36 %	M
0.352	^{211}Bi	14 %	---

TABLE 6 (continued)

Gamma ray^c Energy (MeV)	Emitting Nuclide	Gamma Abundance (% gamma/decay)	Relative Peak Intensity^b Ovserved In Spectra
0.463	^{228}Ac	3.7%	i
0.511	Annihilation ($\beta^- - \beta^+$) peak		i-M
0.511	^{208}Tl	23 %	M
0.583	^{208}Tl	86% γ abundance x 36% α-β branching at ^{212}Bi = 31%	M
0.609	^{214}Bi	47 %	M
0.665	^{214}Bi	---	S
0.727	^{212}Bi	7 %	S
0.77	^{214}Bi	5 %	S
0.83	^{211}Pb	3.4%	S
0.86	^{208}Tl	12 %	S
0.91	^{228}Ac	25 %	i
0.93	^{214}Bi	3 %	S
0.969	^{228}Ac	20 %	i
1.120	^{214}Bi	17 %	i
1.24	^{214}Bi	6 %	S
1.38	^{214}Bi	5 %	S
1.4-1.41	^{214}Bi	4 %	S
1.46	^{40}K	11 %	M
1.50	? (possible random sum peak)	---	S
1.51	^{214}Bi	2.1%	S

TABLE 6 (Continued)

Gamma ray[c] Energy (MeV)	Emitting Nuclide	Gamma Abundance (% gamma/decay)	Relative Peak Intensity[b] Observed in Spectra
1.59	?	---	S
1.66	^{214}Bi	1.1%	S
1.72	?	---	S
1.73	^{214}Bi	2.2%	S
1.765	^{214}Bi	17 %	S-i
1.84	?	---	S
1.849	^{214}Bi	2.7%	S
1.90-1.94	?	---	S

[a] Sample R-9 was used to illustrate the gamma ray spectra obtained

[b] M = major; i = intermediate; S = small

[c] Number of significant figures represents accuracy with which the photopeak is defined

[d] --- indicates overlapping of photopeak with the above listed gamma ray(s). Therefore, only a combined relative peak intensity is listed at the first gamma for this energy.

TABLE 7

CONCENTRATIONS OF SEVERAL NATURALLY OCCURRING RADIOACTIVE NUCLIDES
IN SAMPLES OF FLY ASH, COMBINED ASH AND FGD WASTES

				Nuclide Concentrations (pCi/g)[a]					
Sample	Sample Container Number	Sample Type	Gamma Analysis Time(Sec)	^{228}Ra[b] (as ^{228}Ac) 0.91 MeVγ	^{228}Ra[b] (as ^{228}Ac) 0.96 MeVγ	^{228}Th[b] (as ^{208}Tl) 0.585 MeVγ	^{40}K 1.46 MeVγ	^{238}U(as ^{235}U) 0.186 MeVγ (minus ^{226}Ra Contribution)	Total U(ppm) (as^{235}U)
R-11 (a)	2	fly ash	65,300	2.8	2.7	2.6	8.4		
R-11 (a)	2	fly ash	85,000	2.9	2.4	3.0	8.4	4.4	13.3
R-1(d)	23	fly ash	68,700			3.0	27.6		
R-1(d)	23	fly ash	77,000	3.6	3.2	3.0	26.7		
R-1(d)	23	fly ash	240,700	3.5	2.7	2.9	24.3	4.1	12.3
R-9 (b)	6	Combined ash	58,900			2.4	9.2		
R-9 (b)	6	Combined ash	86,513	2.7	3.0	2.4	9.2		
R-9 (b)	6	Combined ash	[illegible],000	2.9	2.6	2.5	9.3	4.5	13.6
R-18	39	FGD	74,000	N.A.	N.A.	0.5±0.6	<5	N.A.	N.A.
R-18	39	FGD	77,000	N.A.	N.A.	0.2±0.3	0	N.A.	N.A.
R-16	32	FGD with ash	79,300	N.A.	N.A.	1.9	5.6	N.A.	N.A.
R-16	32	FGD with ash	75,800	N.A.	N.A.	1.7	5.6	N.A.	N.A.

[a] Accuracy is ±10% (estimated from calibration data) except as noted for the Sample R-18 which had very low activity and, hence, inferior statistical certainty to the data.

[b] These nuclides occur in the decay chain initiated by ^{232}Th decay. ^{232}Th activity will be similar to these activities if equilibirum exists.

[c] Not Analyzed

TABLE 8

FRACTIONAL RADON-222 EMANATION (%) IN ASH AND FGD WASTE SAMPLES

Sample	Container Number	Sample Type	Gamma Analysis Time(sec)	Fractional Radon Emanation(%)[a]	
				0.352 MeVγ	0.609 MeVγ
R-11 (a)	2	fly ash	65,300-85,000	5 ± 15	(8 ± 15)[c]
R-1(d)	23	fly ash	68,700-240,700	(4 ± 8)	(2 ± 6)
R-2(a)[d]	11	fly ash	60,000	6 ± 9	-
R-9(a)	6	combined fly and bottom ash	58,900-313,000	14 ± 23	2 ± 25
R-18	39	FGD	74,000-77,000	13 ± 69[b]	(66 ±178)[b]
R-16	32	FGD(with ash)	75,800-79,300	7 ± 14	12 ± 18

---

[a] As changes in counts, at the respective energies, of ^{241}Pb and ^{214}Bi between 30 day samples and the same sample (termed "zero" days) following flush of interstitial gases.

[b] These samples had very low initial activities and thus, large relative errors associated with each measurement

[c] Value in parenthesis indicates value for "zero day" sample was larger than 30 day old sample. See note b,

[d] Performed by DOE laboratory (Ref 10) using Marinelli flask. Sample showed no radon growth within experimental error.

The relative concentrations of ^{228}Ra and ^{228}Th (products of ^{232}Th decay) may be used to indicate whether selective pyrochemical separation of Th and Ra occurs as coal is converted to the ash. If some pyrochemical separation occurs the activity ratio of radium to thorium in the ash would be in disequilibrium (unequal) relative to the equilibrium state in the coal. This assumes that the entire decay chain of Th-232 is in equilibrium (all have half-lives of less than 7 years) and that no leaching of thorium versus radium occured in the coal over the last 35 years. Given these assumptions, the data in Table 7 suggest that within the variations observed in the data the ratios in the ash are similar to those that would have existed in coal.

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APPENDIX A

Extraction Procedure Measurements Supplemental Data

Table A-1: Summary of Quality Control Experiments: Data for Blanks

Table A-2: Calculation of Detection Limits

Table A-3: Replicate Extraction Data

TABLE A-1; Summary of Quality Control Experiments Data for Blanks[a]

Sample	Description	No of Samples	As	Ba	Cd	Cr	Hg	Pb	Se	Ag
Total System Blank	pH 5 H_2O carried through complete procedure	6	<2	110	<2	<8	<2	<3	<2	<1
Total Extraction Blank	Total System Blank without final filtration	2	<2	<30	<2	<8	<2	<3	<2	<1
Filter Blank	0.125 N Acetic Acid passed through filters	3	<2	75	<2	<8	<2	<3	<2	<1
Bottle Blank	0.125 N Acetic Acid added to containers used to store extracts	3	<2	<30	<2	<8	<2	<3	<2	<1
Distilled Water Rinse	Final Rinse of Extraction Container prior to initiation of extraction	3	<2	<30	<2	<8	<2	<3	<2	<1

---

[a] All concentrations in μg/l (ppb)

TABLE A-2

Calculations of Detection Limits

Element	Concentration of Standard (ppb)	RSD[a] of Replicate(%)	Detection Level[b] Estimate (ppb)
Ba	200	8.1	<40[c]
	200	7.5	<30
Cr	25	14.6	<8
	75	4.3	<7
As	20	6.8	<3
	20	4.3	<2
Ag	6	5.0	<1
	6	2.6	<1
Pb	6	2.4	<3
	10	5.8	<2
Cd	6	10.7	<2
	10	3.8	<1
Hg	6	9.7	<2
	8	11	<2
Se	20	3.5	<2
	6	9.6	<2

---

[a] RSD - Relative Standard Deviation of replicates (at least 3)

[b] Detection Limit = 2 x RSD x Concentration of Standard

[c] Detection Limit of 100 ppb was used due to filter blank values. See text.

TABLE A-3: Replicate Extraction Data

Sample	Concentration (μg/l)							
	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
Fly Ash:								
EP-1c	<1	98	510	16	8	<2	<3	39
EP-1c (replicate)	<1	98	240	16	12	<2	<3	52
EP-2a	<1	<5	750	<2	240	<2	<3	20
EP-2a(replicate)	<1	<5	1200	<2	220	<2	<3	20
EP-17	<1	6	500	<2	14	<2	<3	5
EP-17(replicate)	<1	6	460	<2	8	<2	<3	9

APPENDIX B

Radioactivity Measurements

Supplemental Data

Table B-1: ^{226}Ra Concentrations based on 0.352 MeV and 0.609 MeV gamma rays

Figure B-1: Gamma Ray Energy *vs* Channel Number Calibration

Figure B-2: Absolute Counting Efficiency *vs* Gamma Ray Energy Calibration

TABLE B-1

Radium-226 Concentration in Sealed Fly Ash, Bottom Ash and FGD Samples Based on High Resolution Gamma Spectroscopy of the 0.352 MeV Gamma Ray (^{214} Pb) and the 0.609 MeV Gamma Ray (^{214}Bi).

Sample Type	Container Number	Sample[a]	Sample Net Wt. (g)	Gamma Ray Analysis Time(sec)	^{226}Ra Concentration (pCi/g sample)[b] Based on 0.352 MeV gamma	Based on 0.609 MeV gamma	Average
Fly Ash:	2	R-11(a)	263.8	13,400	3.7 ± 0.4	3.8 ± 0.4	3.8 ± 0.3
	5	R-7 (a)	244.3	77,400	4.1 ± 0.2	4.0 ± 0.3	4.1 ± 0.2
	7	R-5(b)	256.2	58,503	2.6 ± 0.2	2.9 ± 0.3	3.1 ± 0.1
	7	R-5(b)	256.2	251,000	3.5 ± 0.1	3.6 ± 0.1	
	8	R-8(a)	258.5	241,500	4.9 ± 0.1	4.8 ± 0.1	4.1 ± 0.1
	9	R-15(a)	214.4	8,452	3.5 ± 0.7	4.0 ± 0.6	3.8 ± 0.5
	10	R-9 (a)	248.0	6,080	3.9 ± 0.7	3.8 ± 0.6	3.9 ± 0.5
	11	R-2(a)	266.7	59,000	3.0 ± 0.2	2.8 ± 0.2	2.9 ± 0.1
	12	R-2(b)	189.5	8,000	3.8 ± 0.6	3.9 ± 0.8	3.9 ± 0.5
	20	R-2(a)	279.7	74,300	2.8 ± 0.2	3.2 ± 0.3	2.9 ± 0.1
	20	R-2(a)	279.7	57,380	2.9 ± 0.2	2.9 ± 0.2	
	21	R-2(a)	290.4	429,195	2.8 ± 0.1	2.6 ± 0.1	
	21	R-2(a)	290.4	57,510	3.3 ± 0.3	3.2 ± 0.2	
	21	R-2(a)	290.4	15,800	2.7 ± 0.4	2.5 ± 0.4	
	22	R-14	214.9	24,000	4.3 ± 0.4	4.6 ± 0.5	4.5 ± 0.3
	23	R-1(d)	144.7	27,600	N.A.	4.3 ± 0.3	4.3 ± 0.3
	24	R-6 (a)	129.1	26,400	4.8 ± 0.4	4.5 ± 0.5	4.7 ± 0.3
	25	R-5(a)	85.5	57,200	3.0 ± 0.3	3.7 ± 0.4	3.4 ± 0.3
	26	P-13(a)	140.7	54,430	1.9 ± 0.3	1.7 ± 0.3	1.8 ± 0.2

TABLE B-1 (Continued)

Sample Type	Container Number	Sample[a]	Sample Net Wt. (g)	Gamma Ray Analysis Time(sec)	^{226}Ra Concentration (pCi/g sample)[b] Based on 0.352 MeV gamma	Based on 0.609 MeV gamma	Average
Fly Ash (Cont)	27	R-4(a)	66.9	26,900	4.6 ± 0.7	4.8 ± 0.8	4.7 ± 0.5
	28	R-1(a)	115.3	57,800	3.2 ± 0.3	3.8 ± 0.5	3.5 ± 0.3
	29	R-12(c)	174.5	56,400	3.9 ± 0.3	4.1 ± 0.4	4.0 ± 0.3
	30	R-1(b)	175.2	23,400	4.4 ± 0.5	4.0 ± 0.5	4.2 ± 0.4
	31	R-1(c)	195.0	62,300	4.2 ± 0.3	4.4 ± 0.4	4.3 ± 0.3
	38	R-13(a)	241.0	27,550	2.2 ± 0.3	1.8 ± 0.3	2.0 ± 0.2
	15	R-3 (a)	219.5	57,200	3.3 ± 0.2	3.4 ± 0.2	3.4 ± 0.1
	16	R-10(a)	202.2	8,000	2.6 ± 0.8	3.0 ± 0.6	2.9 ± 0.3
	16	R-10(a)	202.2	16,000	2.8 ± 0.7	3.0 ± 0.6	
Bottom Ash	1	R-7(b)	352.7	59,700	3.0 ± 0.4	3.4 ± 0.3	3.2 ± 0.3
	3	R-10(b)	158.6	9,300	2.4 ± 0.7	3.1 ± 0.6	2.8 ± 0.5
	14	R-5(c)	134.2	6.610	3.9 ± 0.8	4.3 ± 1.0	4.1 ± 0.6
	18	R-12(a)	202.0	57,000	4.4 ± 0.2	4.5 ± 0.3	4.5 ± 0.2
	19	R-12(b)	140.9	18,600	4.1 ± 0.5	4.2 ± 0.8	4.2 ± 0.5
	33	R-3 (b)	203.0	58,700	1.7 ± 0.3	2.0 ± 0.3	1.9 ± 0.2
	34	R-11 (b)	195.0	241.620	1.8 ± 0.2	2.0 ± 0.2	1.9 ± 0.1
	35	R-2(c)	334.7	58,500	1.7 ± 0.3	1.6 ± 0.3	1.7 ± 0.2

TABLE B-1 (Continued)

Sample Type	Container Number	Sample[a]	Sample Net Wt. (g)	Gamma Ray Analysis Time(sec)	^{226}Ra Concentration (pCi/g sample)[b] Based on 0.352 MeV gamma	Based on 0.609 MeV gamma	Average
Combined Fly and Bottom Ash	4	R-15(b)	168.5	54,500	2.9 ± 0.3	3.2 ± 0.3	3.1 ± 0.2
	6	R-9 (b)	231.9	8,300	3.7 ± 0.6	3.4 ± 0.9	3.6 ± 0.5
Boiler Slag	13	R-4 (b)	298.4	7,200	2.4 ± 0.4	2.1 ± 0.8	2.3 ± 0.4
	17	R-6 (b)	275.5	59,500	3.6 ± 0.2	3.4 ± 0.2	3.5 ± 0.1
FGD	32	R-16	73.2	243,230	2.9 ± 0.3	3.3 ± 0.3	3.1 ± 0.2
	36	R-8 (b)	37.5	16,000	0.8 ± 0.8	1.0 ± 1.0	0.9 ± 0.6
	37	R-13(b)	42.2	52,660	0.6 ± 1.6	0.4 ± 0.6	<1.3
	39	R-18	40.1	74,000	0.4 ± 0.2	0.2 ± 0.1	0.3 ± 0.1

---

[a] Samples listed according to code given to various plants

[b] Error (± 1 standard deviation) based on gamma ray counting statistics (See reference 11).

GAMMA RAY ENERGY VS. CHANNEL NUMBER FOR
Ge(Li) GAMMA RAY DETECTOR

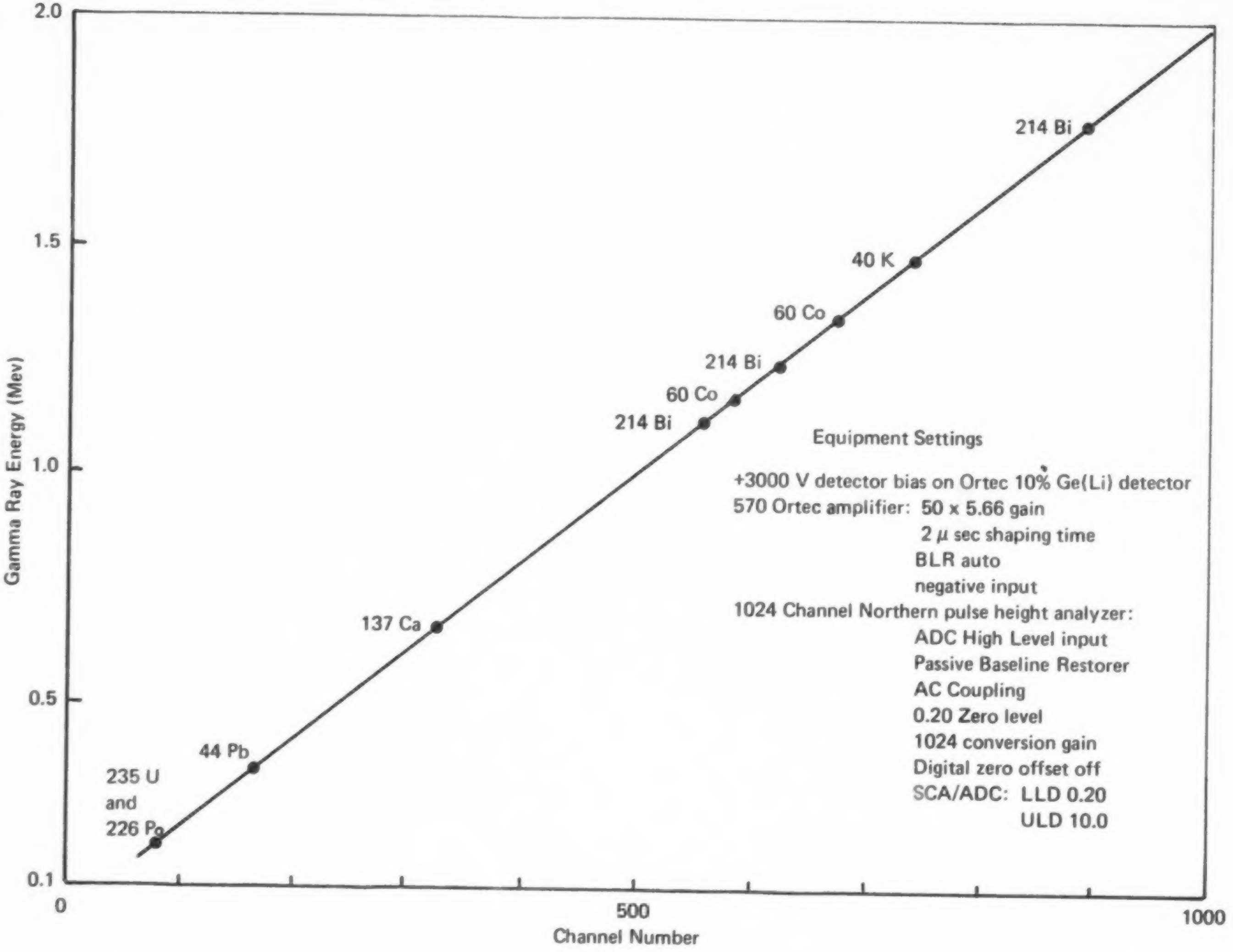
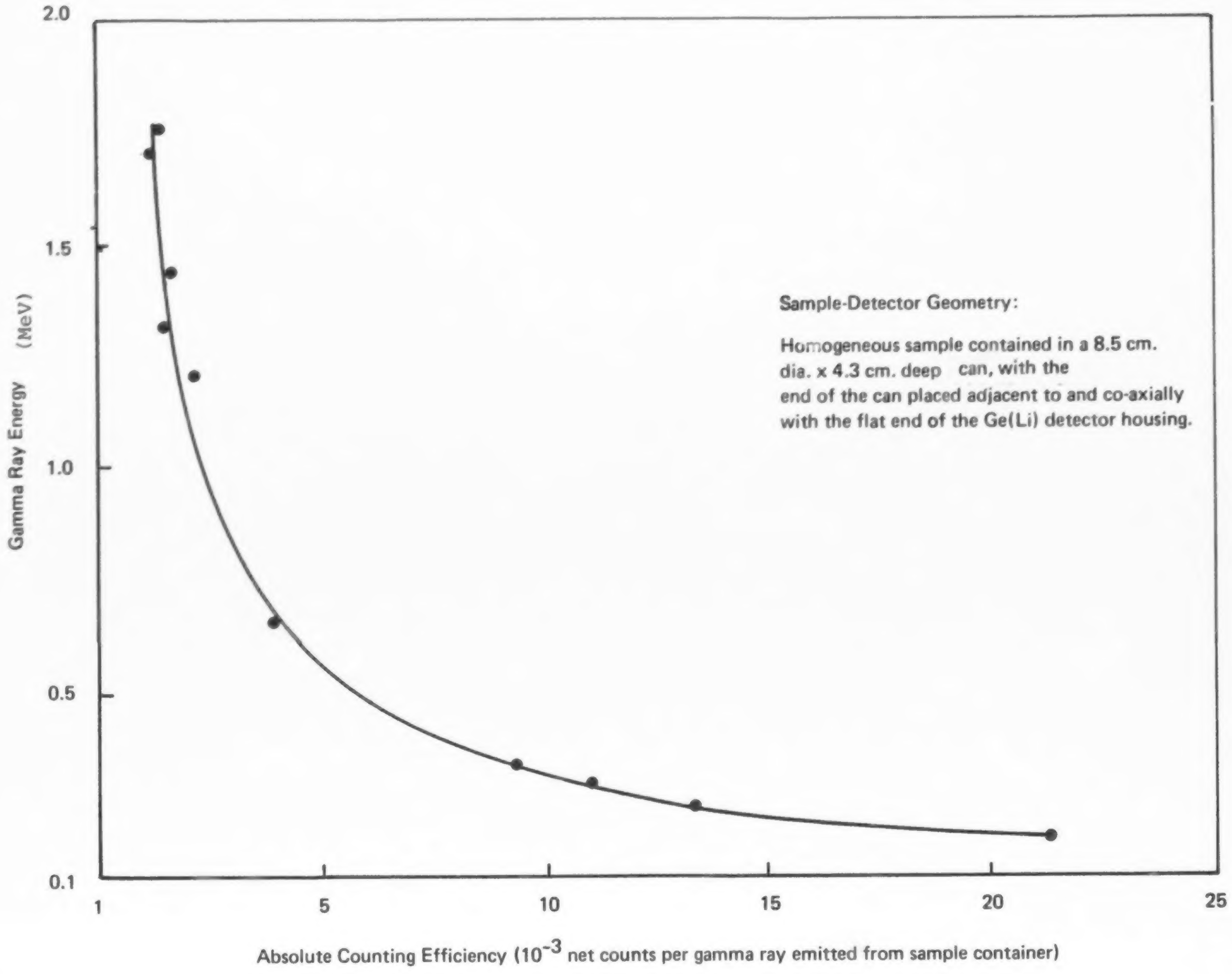


FIGURE B-1

ABSOLUTE COUNTING EFFICIENCY AS A FUNCTION OF THE GAMMA RAY ENERGY FOR A FIXED SAMPLE/DETECTOR GEOMETRY



Sample-Detector Geometry:

Homogeneous sample contained in a 8.5 cm. dia. x 4.3 cm. deep can, with the end of the can placed adjacent to and co-axially with the flat end of the Ge(Li) detector housing.

FIGURE B-2

APPENDIX E

PHYSICAL SAMPLING AND ANALYSIS DATA

FULL-SCALE FIELD EVALUATION OF WASTE DISPOSAL FROM COAL-FIRED ELECTRIC GENERATING PLANTS

By

Chakra J. Santhanam
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Itamar Bodek
Charles B. Cooper
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EPA Contract 68-02-3167

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APPENDIX E

Physical Sampling and Analysis Data

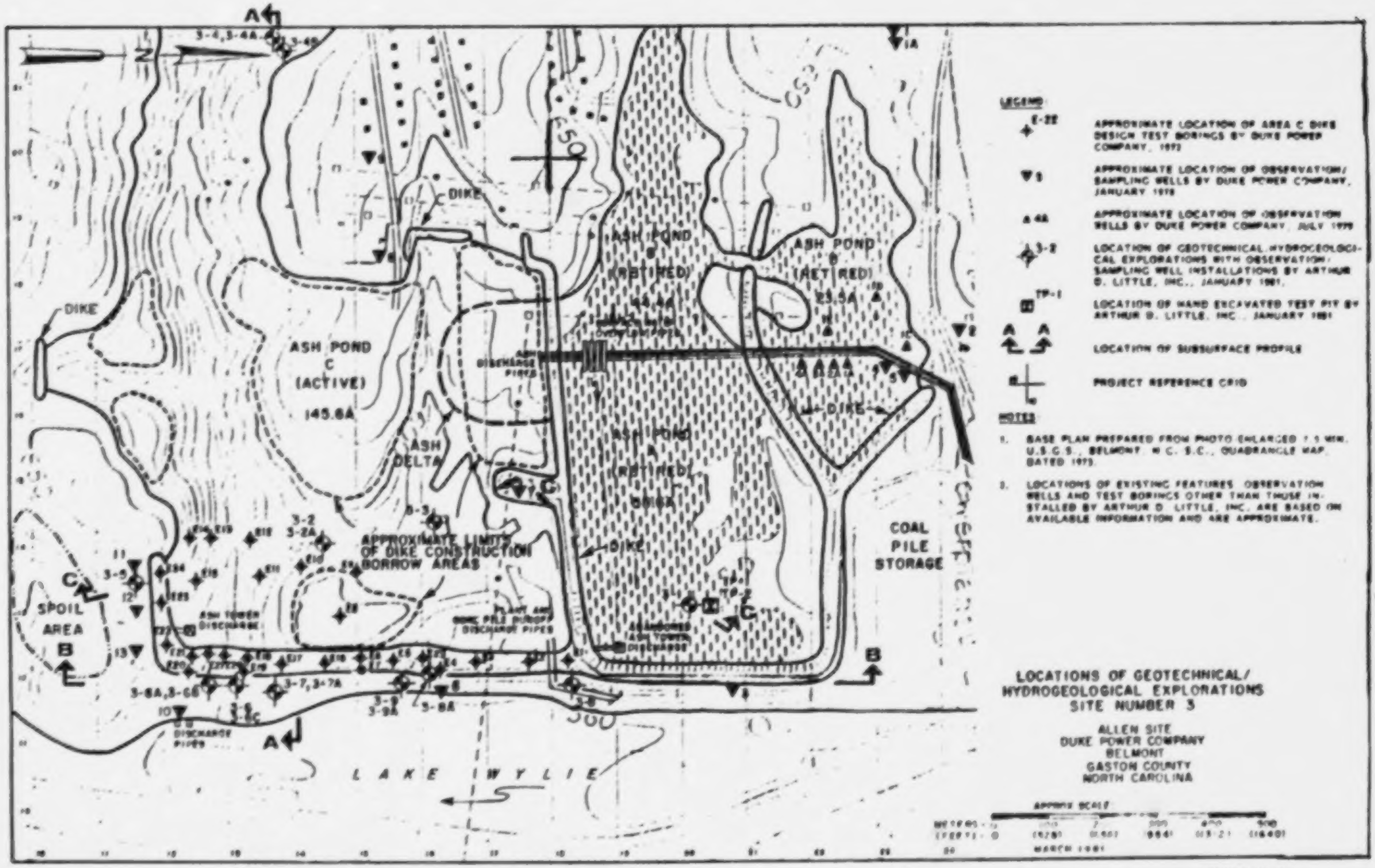
This appendix provides the physical sampling and analysis data as discussed in the main body of the report. This appendix contains data in the following areas for each site.

- site map
- QA/QC results
- permeability data (constant head)
- void ratio vs pressure
- extended permeability tests (limited number of sites)
- unconsolidated - undrained triaxial tests (limited number of sites)
- specific gravity
- soil classifications
- data summary sheets

These data are reported by site in the following sections.

	Page
• Allen	E-3
• Elrama	E-43
• Dave Johnston	E-114
• Sherco	E-153
• Smith	E-191
• Powerton	E-226

Allen Duke Power


ASH POND
C
(ACTIVE)
145.6A
ASH POND
B
(RETIRED)
44.4A
ASH POND
D
(RETIRED)
23.5A
ASH POND
A
(RETIRED)
ASH DELTA
DIKE
APPROXIMATE LIMITS OF DIKE CONSTRUCTION BORROW AREAS
SPOIL AREA
COAL PILE STORAGE
LAKE WYLIE
DISCHARGE PIPES
ASH TOWER DISCHARGE
PLANT AND COAL PILE RUNOFF DISCHARGE PIPES
ABANDONED ASH TOWER DISCHARGE
A
B
C
N
3-2
3-2A
3-4, 3-4A
3-5
3-6A, 3-6B
3-7, 3-7A
3-8A
3-9
3-9A
TP-1
TP-2
650
560

LEGEND:

E-22 APPROXIMATE LOCATION OF AREA C DIKE DESIGN TEST BORINGS BY DUKE POWER COMPANY, 1972

▼1 APPROXIMATE LOCATION OF OBSERVATION/SAMPLING WELLS BY DUKE POWER COMPANY, JANUARY 1978

▲4A APPROXIMATE LOCATION OF OBSERVATION WELLS BY DUKE POWER COMPANY, JULY 1979

3-2 LOCATION OF GEOTECHNICAL/HYDROGEOLOGICAL EXPLORATIONS WITH OBSERVATION/SAMPLING WELL INSTALLATIONS BY ARTHUR D. LITTLE, INC., JANUARY 1981.

TP-1 LOCATION OF HAND EXCAVATED TEST PIT BY ARTHUR D. LITTLE, INC., JANUARY 1981

A A LOCATION OF SUBSURFACE PROFILE

PROJECT REFERENCE GRID

NOTES:

1. BASE PLAN PREPARED FROM PHOTO ENLARGED 7.5 MIN. U.S.G.S., BELMONT, N.C. S.C., QUADRANGLE MAP, DATED 1973.
2. LOCATIONS OF EXISTING FEATURES, OBSERVATION WELLS AND TEST BORINGS OTHER THAN THOSE INSTALLED BY ARTHUR D. LITTLE, INC. ARE BASED ON AVAILABLE INFORMATION AND ARE APPROXIMATE.

LOCATIONS OF GEOTECHNICAL/
HYDROGEOLOGICAL EXPLORATIONS
SITE NUMBER 3

ALLEN SITE
DUKE POWER COMPANY
BELMONT
GASTON COUNTY
NORTH CAROLINA

APPROX SCALE
METERS 0 100 200 300 400 500
(FEET) 0 (328) (656) (984) (1312) (1640)
MARCH 1981

FIGURE 5.4

Reproduced from
best available copy.

EPA CONTRACT 68-02-3167

ADL CASE 84000

PHYSICAL TESTING RESULTS

1.0	ALLEN	DUKE POWER
2.0	ELRAMA	DUQUESNE LIGHT & CSI
3.0	DAVE JOHNSTON	PACIFIC POWER & LIGHT
4.0	SHERCO	NORTHERN STATES POWER
5.0	POWERTON	COMMONWEALTH EDISON
6.0	LANSING SMITH	GULF POWER

UNIVERSITY OF LOUISVILLE
LOUISVILLE, KENTUCKY 40292

SPEED SCIENTIFIC SCHOOL
JAMES BRECKENRIDGE SPEED FOUNDATION
DEPARTMENT OF CIVIL ENGINEERING

September 23, 1981

MEMORANDUM TO: C. J. Santhanam, ADL

FROM.........: C. R. Ullrich, UL CRUllrich

SUBJECT......: QA/QC Physical Property Tests

Please find attached a summary of results of QA/QC tests performed at the University of Louisville on samples from the Allen Plant. All samples tested consisted of ash materials, thus unconfined compression tests could not be performed. Test results are reported for permeability tests performed on remolded, compacted samples representing three depth intervals.

QA/QC physical property tests on Shelby tube samples and jar samples from Sherco are under way. We will provide results to you when testing is completed.

lw

SUMMARY OF RESULTS

QA/QC PHYSICAL PROPERTY TESTS

ALLEN PLANT

Boring No.: 3-1

Sample No.: 5C

Depth: 20'0" - 22'0"

Date of sampling: January 22, 1981

*Results of permeability tests on remolded, compacted samples:

Depth Interval (ft.)	Material	Water Content (%)	Moist Density (pcf)	Dry Density (pcf)	Coefficient of Permeability (cm/sec)
20'0"-20'8"	ash	5.0	110.4	104.8	4.27×10^{-3}
20'8"-21'2"	ash	6.0	116.1	109.2	2.29×10^{-3}
21'2"-22'0"	ash	35.8	104.2	76.8	2.00×10^{-3}

CONSTANT HEAD
PERMEABILITY TEST
LABORATORY COMPACTED

Project: Allen Disposal Site
Material Description: Flyash
Method of Compaction: Puddled into mold

SPECIMEN DATA

Compaction:
  Maximum Dry Unit Weight: 63.7 pcf
  Optimum Moisture Content: 14.5%
  Test Method: ASTM-D698-70-Method "C" Standard
Dimensions:
  Height: 4.002"
  Diameter: 4.505"
Weight:
  Initial: 3.00 lbs.
Moisture Content:
  Initial: 55.6%
  Final: 57.5%
Wet Unit Weight:
  Initial: 81.3 pcf
  Final: 82.2 pcf
Dry Unit Weight:
  Initial: 52.2 pcf
  % Compaction: 81.9
Back Pressure Saturation:
  Pressures: 5.0 psi
Permeability:
  $k =$ 2×10^{-4} cm/sec

Calculations:

Formula: $k=\frac{QLC}{thD^2}$

Where for lost reading:
$Q=161$ cc
$L=4.505$"
$t=378$ seconds
$h=5.0$ psi
$D^2=16.016$ inches^2
$C=0.0071297$
$k=2 \times 10^{-4}$ cm/sec

Constant Head

Permeability Test

Project:	Allen Disposal Site
Boring No.:	3-1A
Sample No.:	1B
Depth Interval of Sample:	4.0' - 5.5'
Depth Interval of Test Specimen:	4.5' - 5.0'

SPECIMEN DATA:

Dimensions, inches,	
Height:	5.968"
Diameter:	2.931"
Weight, lbs.,	
Initial:	1.85
Moisture Content, %:	
Initial:	35.6
Final:	43.9
Wet Unit Weight, pcf,	
Initial:	79.4
Final:	84.3
Dry Unit Weight, pcf,	
Initial:	58.6
Back Pressure Saturation, psi,	
Pressures:	10.0
Material Description:	Gray Flyash
Permeability, cm/sec,	
k:	9×10^{-6}

Calculations:

Formula: $k=\frac{QLC}{thD^2}$

Where for last reading:

$Q=53.1$ cc
$L=5.968"$
$t=2940$ seconds
$h=10.0$ psi
$D^2=8.590$ inches^2
$C=0.0071297$
$k=9 \times 10^{-6}$ cm/sec

Constant Head

Permeability Test

Project: Allen Disposal Site
Boring No.: 3-ITPI
Sample No.: 5C
Depth Interval of Sample: 1.5' - 3.0'
Depth Interval of Test Specimen: 1.5' - 2.0'

SPECIMEN DATA:

Dimensions, inches,
  Height: 5.953
  Diameter: 2.854
Weight, lbs.,
  Initial: 2.20
Moisture Content, %:
  Initial: 36.3
  Final: 35.4
Wet Unit Weight, pcf,
  Initial: 99.8
  Final: 99.1
Dry Unit Weight, pcf,
  Initial: 73.2
Back Pressure Saturation, psi,
  Pressures: 10.0
Material Description: Gray Flyash
Permeability, cm/sec,
  k: 2×10^{-5}

Calculations:

Formula: $k = \frac{QLC}{thD^2}$

Where for Last Reading:
$Q=47.7$ cc
$L=5.953"$
$t=1500$ seconds
$h=10.0$ psi
$D^2=8.145$ inches^2
$C=0.0071297$
$k=2 \times 10^{-5}$ cm/sec

CONSTANT HEAD
PERMEABILITY TEST
LABORATORY COMPACTED

Project: Allen Disposal Site
Material Description: Flyash
Method of Compaction: Static

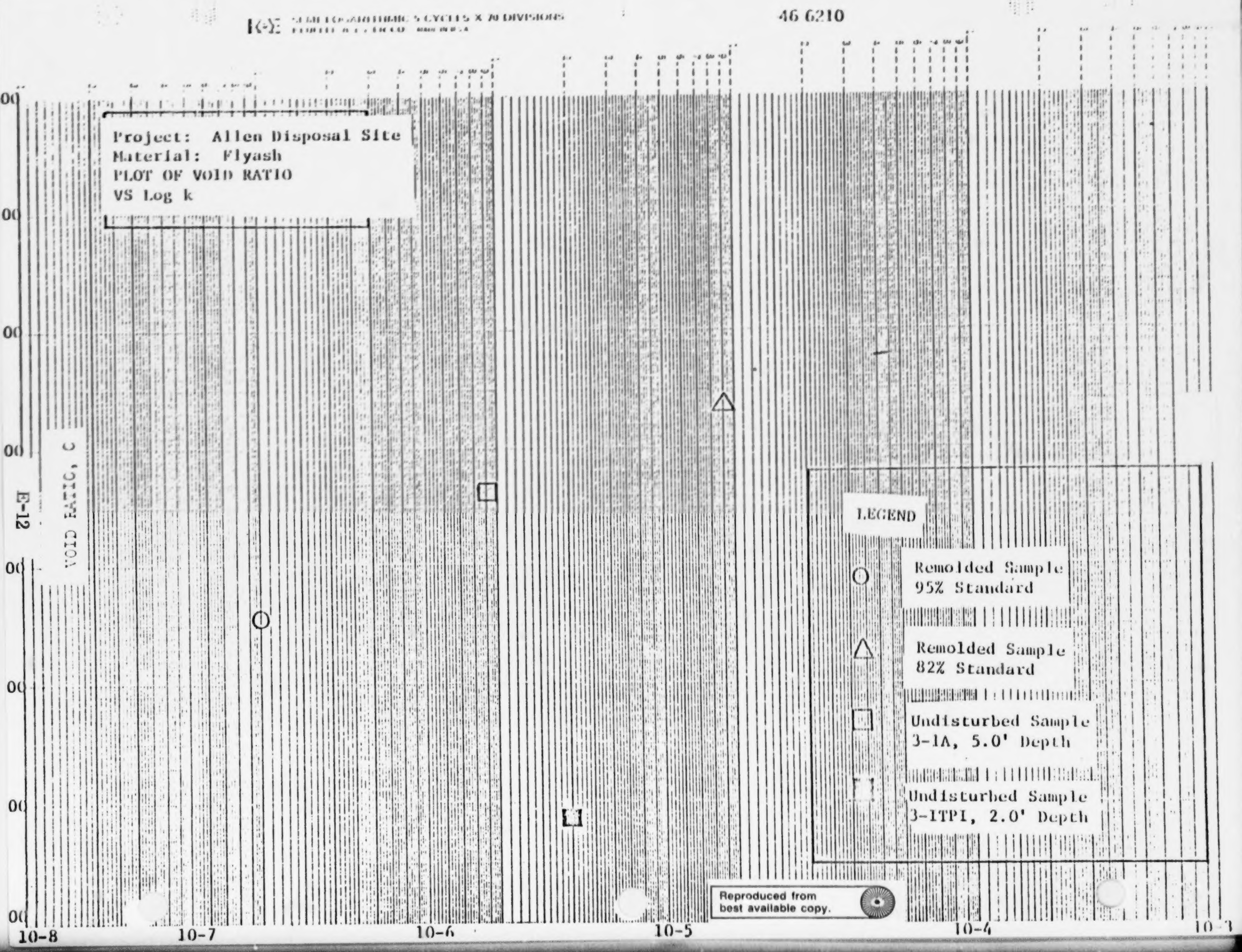
SPECIMEN DATA

Compaction:
  Maximum Dry Unit Weight: 63.7 pcf
  Optimum Moisture Content: 14.5%
  Test Method: ASTM-D698-70-Method "C" Standard
Dimensions:
  Height: 1.978"
  Diameter: 2.684"
Weight:
  Initial: 0.47 lbs.
Moisture Content:
  Initial: 18.2%
  Final: 42.1%
Wet Unit Weight:
  Initial: 72.6 pcf
  Final: 87.2 pcf
Dry Unit Weight:
  Initial: 61.4 pcf
  % Compaction: 96.4
Back Pressure Saturation:
  Pressures: 10.0 psi
Permeability:
  K = 1×10^{-7} cm/sec

Calculations:

Formula: $k=\frac{QLC}{thD^2}$

Where at last reading:
$Q=17$ cc
$L=1.978"$
$t=25200$ seconds
$h=10.0$ psi
$D^2=7.204$ inches^2
$C=0.0071297$
$k=1 \times 10^{-7}$ cm/sec



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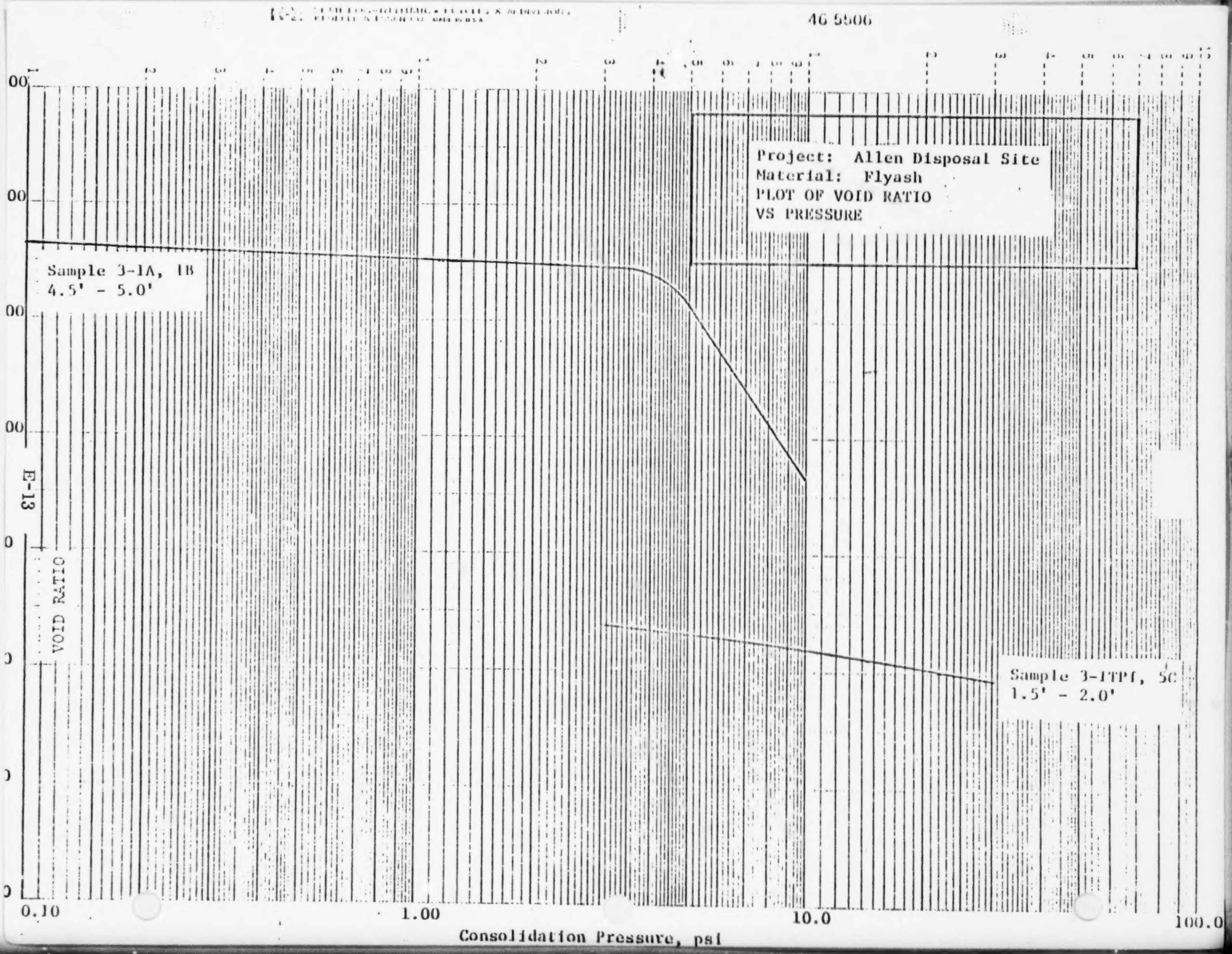
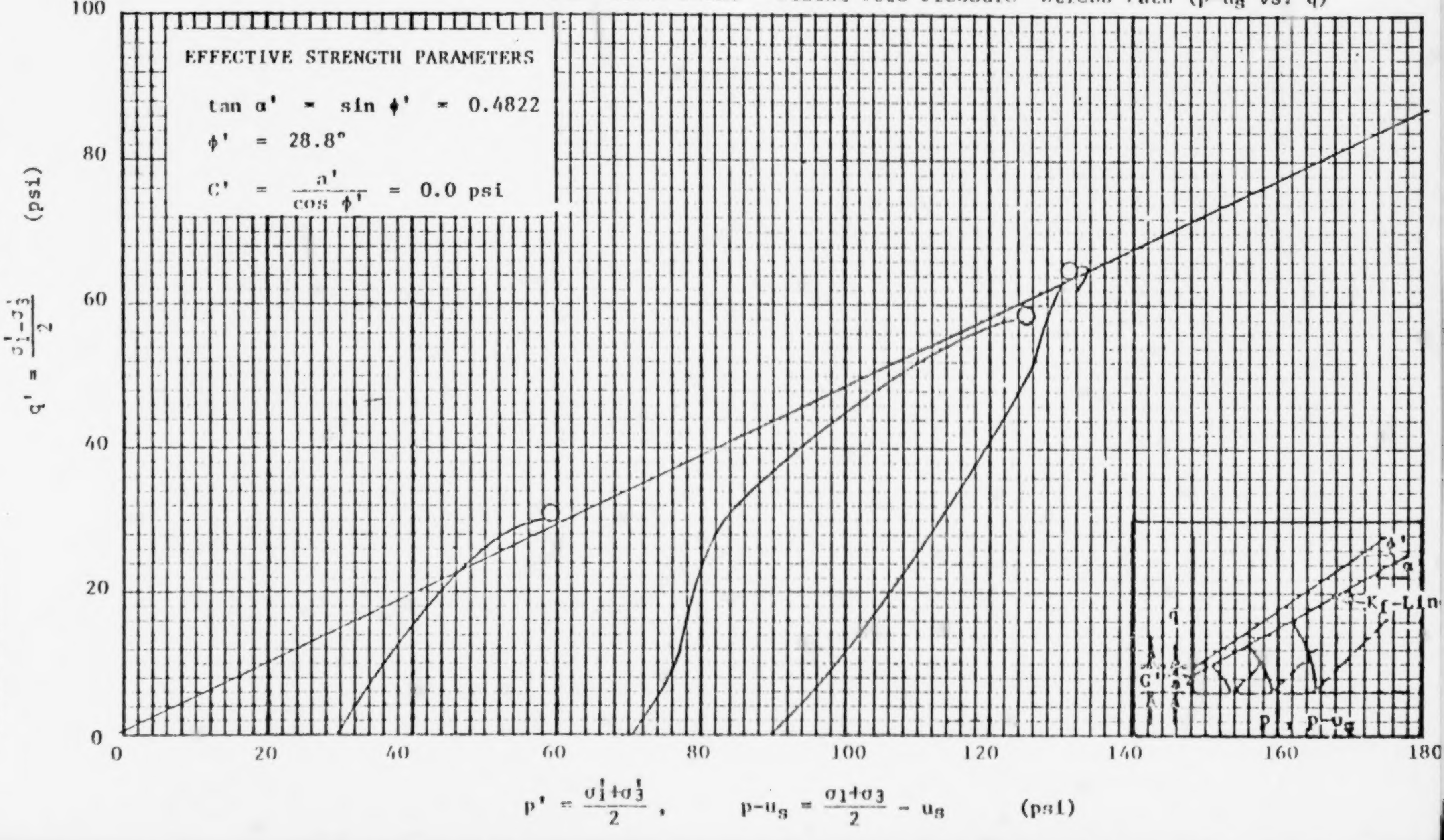

46 5506
Project: Allen Disposal Site
Material: Flyash
PLOT OF VOID RATIO
VS PRESSURE
Sample 3-1A, 1B
4.5' - 5.0'
Sample 3-1TPf, 5C
1.5' - 2.0'
VOID RATIO
0.10
1.00
10.0
100.0
Consolidation Pressure, psi

CONSOLIDATED-UNDRAINED TRIAXIAL STRESS PATHS

TEST NO. 1

Project: Arthur D. Little, Allen Disposal Site
Material: Fill of dark gray flyash, source; 3-ITP-1, 5C; 3-1A, 1B

0 = Maximum Principal Effective Stress Ratio
——————— = Effective Stress Path (p' vs. q)
— — — — = "Total Stress Point - Static Pore Pressure" Stress Path ($p-u_s$ vs. q)



EFFECTIVE STRENGTH PARAMETERS

$\tan \alpha' = \sin \phi' = 0.4822$

$\phi' = 28.8°$

$C' = \frac{a'}{\cos \phi'} = 0.0$ psi

CONSOLIDATED-UNDRAINED TRIAXIAL TEST SUMMARY

SAMPLE CONDITIONS

	Test Sample 1	Test Sample 2	Test Sample 3	Test Sample 4	Test Sample 5
Sample Preparation:	- Undisturbed -				
Material:	Fill of Gray Flyash				
Boring No.:	3-ITPI	3-ITPI	3-1A		
Sample No.:	5C	5C	1B		
Depth (ft):	2.0-2.5	1.5-2.0	4.5-5.0		
Lateral Pressure (psi),					
Saturation Phase:	15.0	15.0	15.0		
Consolidation Phase:	40.0	70.0	100.0		
Back Pressure (psi),					
Saturation Phase:	10.0	10.0	10.0		
Consolidation Phase:	10.0	10.0	10.0		
Effective Consolidation Pressure (psi):	30.0	60.0	90.0		
Skempton B-Value at Initiation of Consolidation Phase:	0.37	1.00*	1.00*		
Deformation Rate, (Inches Per Minute):	0.01	0.01	0.01		
Specimen Weight (lbs):	2.04	2.20	1.85		
Specimen Height (in),					
Initial:	5.930	5.953	5.968		
Consolidated:	5.664	5.928	5.904		
End of Test:	4.531	4.742	4.723		
Specimen Diameter (in),					
Initial:	2.838	2.854	2.838		
Consolidated:	2.711	2.842	2.808		
Moisture Content (%),					
Initial:	43.6	36.3	35.6		
Final:	48.0	38.7	48.8		
Wet Unit Weight (pcf),					
Initial:	94.0	99.8	84.3		
Consolidated:	111.1	102.9	95.6		
Dry Unit Weight (pcf),					
Initial:	65.5	73.2	62.2		
Consolidated:	75.1	74.2	64.2		
Specific Gravity:		2.18			
Degree of Saturation (%),					
Initial:	88.0	92.3	65.2		
Final:	100.0	100.0	95.3		
At Maximum Principal Effective Stress Ratio,					
$p' = (\sigma'_1 + \sigma'_3)/2$, (psi):	58.5	124.6	130.5		
$q' = (\sigma'_1 - \sigma'_3)/2$, (psi):	30.4	58.3	64.6		

*Saturated before consolidation

Measured Strength Parameters:

Effective ϕ' (°) = 28.8°

C' (psi) = 0.0

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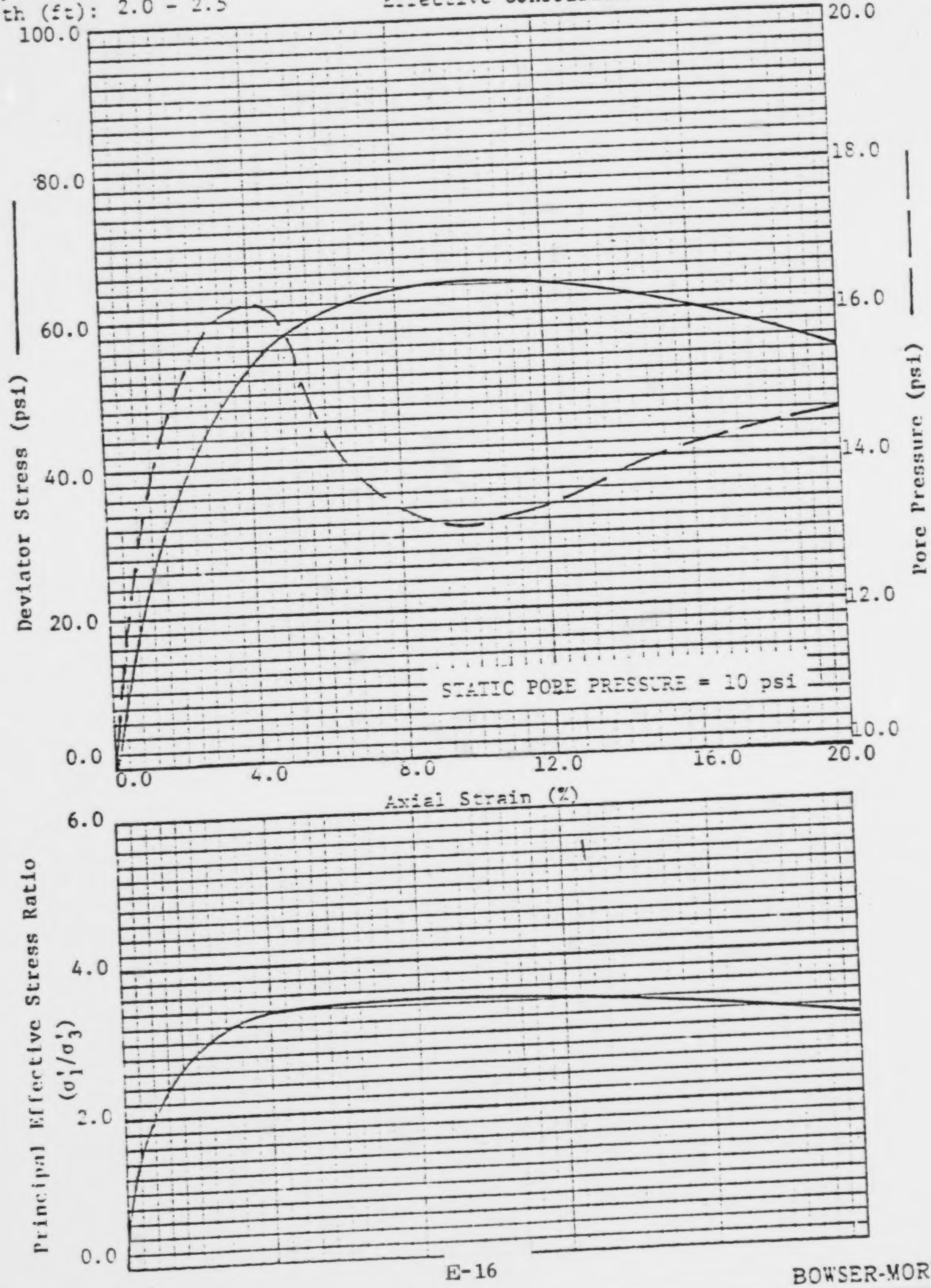
CONSOLIDATED-UNDRAINED TRIAXIAL TEST

TEST NO. 1
SAMPLE NO. 1

Project: Arthur D. Little, Allen Disposal Site
Material: Fill of Gray Flyash

Boring No: 3-ITPI
Sample No: 5C
Depth (ft): 2.0 - 2.5

Lateral Pressure (psi): 40.0
Back Pressure (psi): 10.0
Effective Consolidation Pressure (psi): 30.0



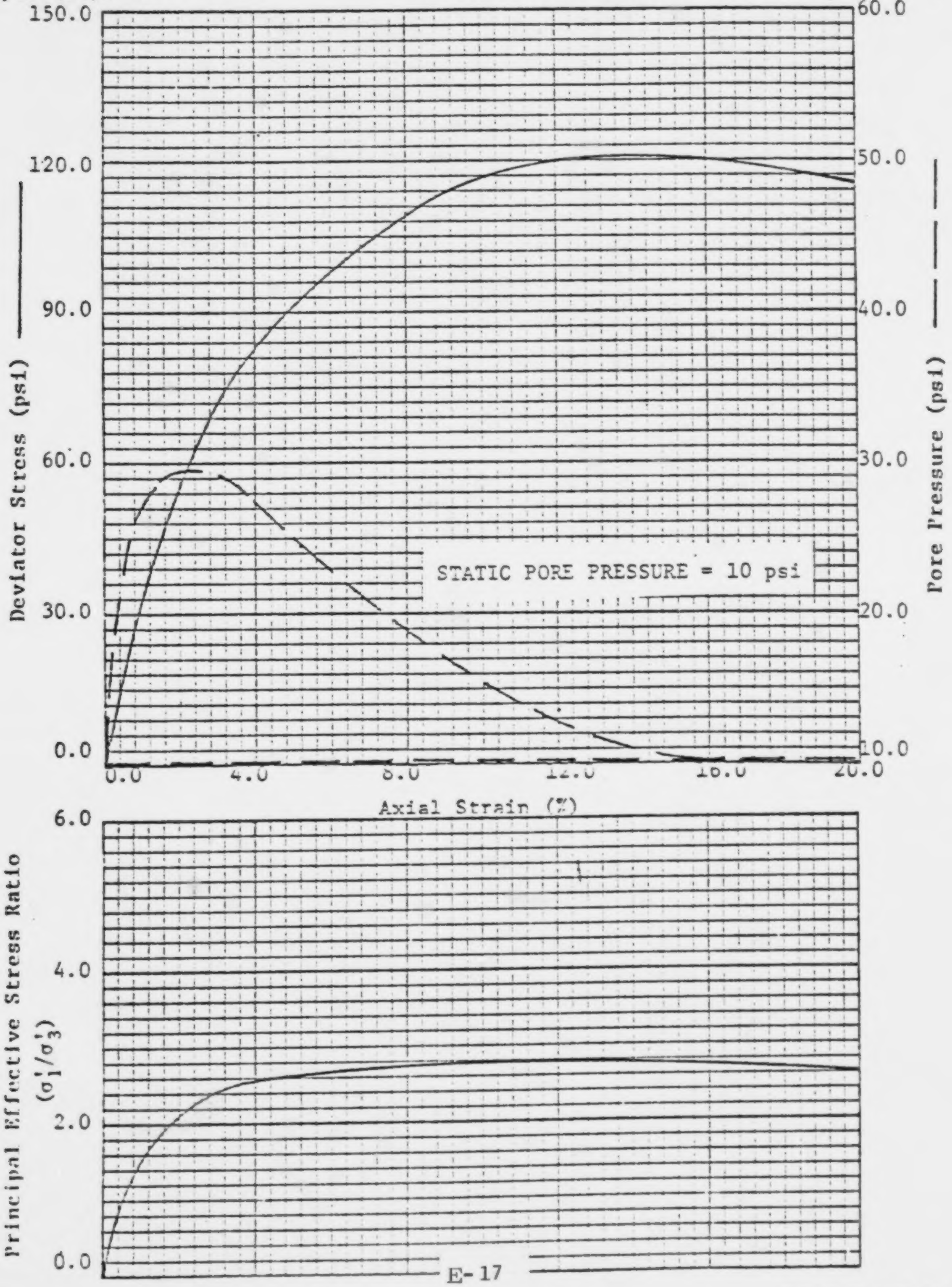
CONSOLIDATED-UNDRAINED TRIAXIAL TEST

TEST NO. 1
SAMPLE NO. 2

Project: Arthur D. Little, Allen Disposal Site
Material: Fill of Gray Flyash

Boring No: 3-ITPI
Sample No: 5C
Depth (ft): 1.5 - 2.0

Lateral Pressure (psi): 70.0
Back Pressure (psi): 10.0
Effective Consolidation Pressure (psi): 60.0



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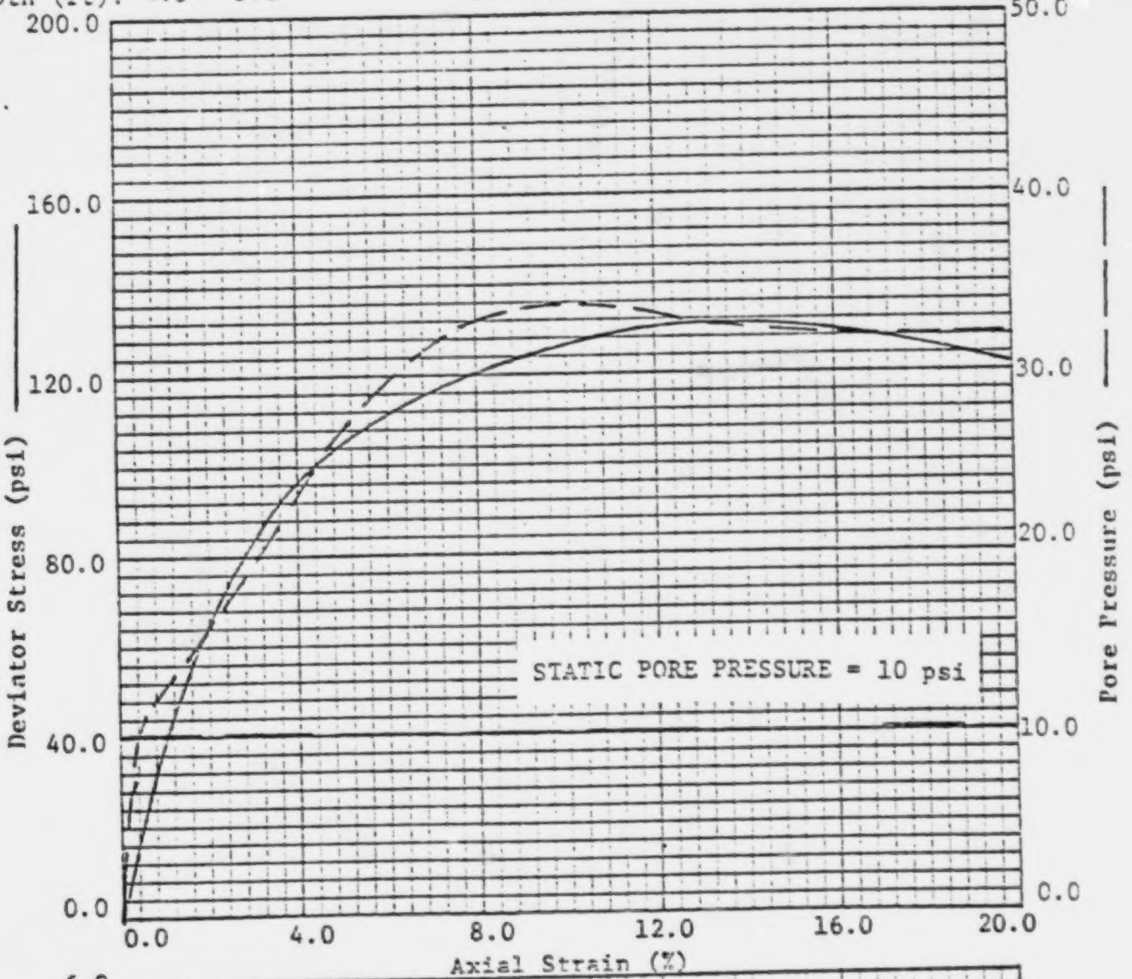
CONSOLIDATED-UNDRAINED TRIAXIAL TEST

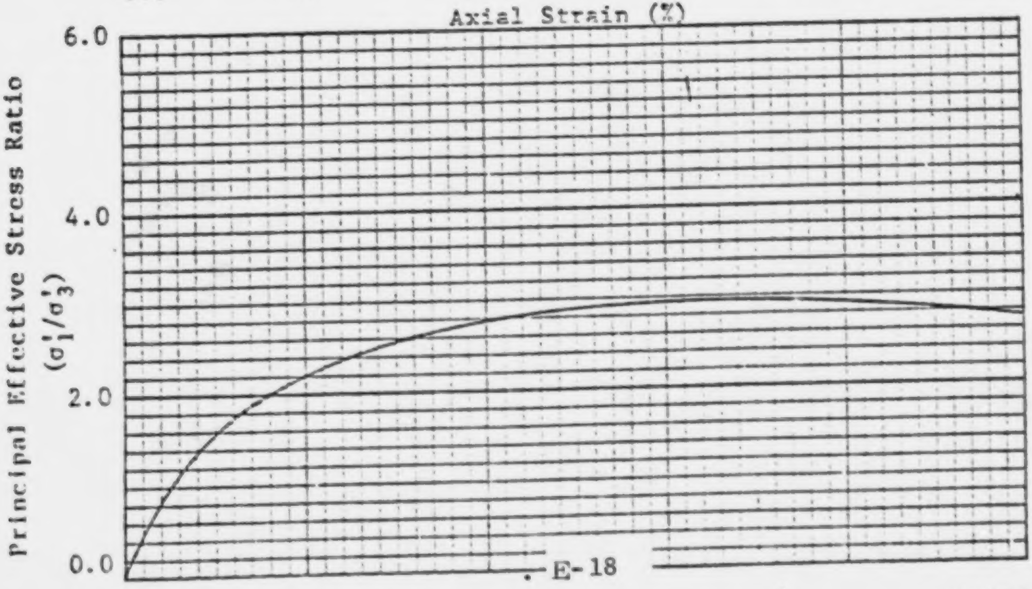
TEST NO. 1
SAMPLE NO. 3

Project: Arthur D. Little, Allen Disposal Site
Material: Fill of Gray Flyash

Boring No: 3-1A
Sample No: 1B
Depth (ft): 4.5 - 5.0

Lateral Pressure (psi): 100.0
Back Pressure (psi): 10.0
Effective Consolidation Pressure (psi): 90.0



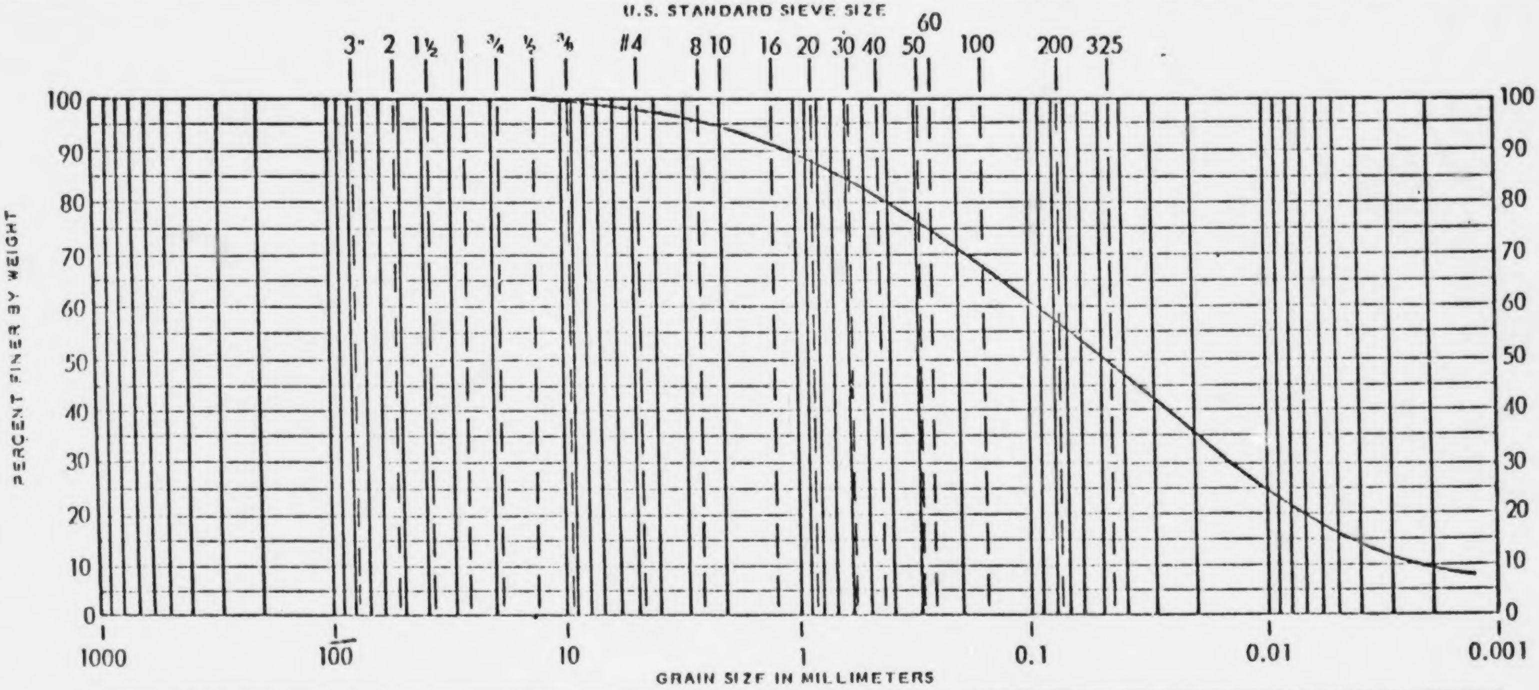


SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Allen Disposal Site

Boring #	Sample #		Specific Gravity
3-1A	1B		2.18
3-2	5A-1		1.96
3-2	8A-1		2.09
3-3	1A-1		2.20
3-3	4A-1		2.02
3-ITPI	5C		2.15
Bag Sample			2.08
		Average	2.10

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 2%		SAND 41%			SILT 41%	CLAY 16%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3
SAMPLE NO. 3A
DEPTH 16.0' - 18.0'
CLASSIFICATION "ML"
Sandy Silt

NATURAL % MOISTURE 29.4
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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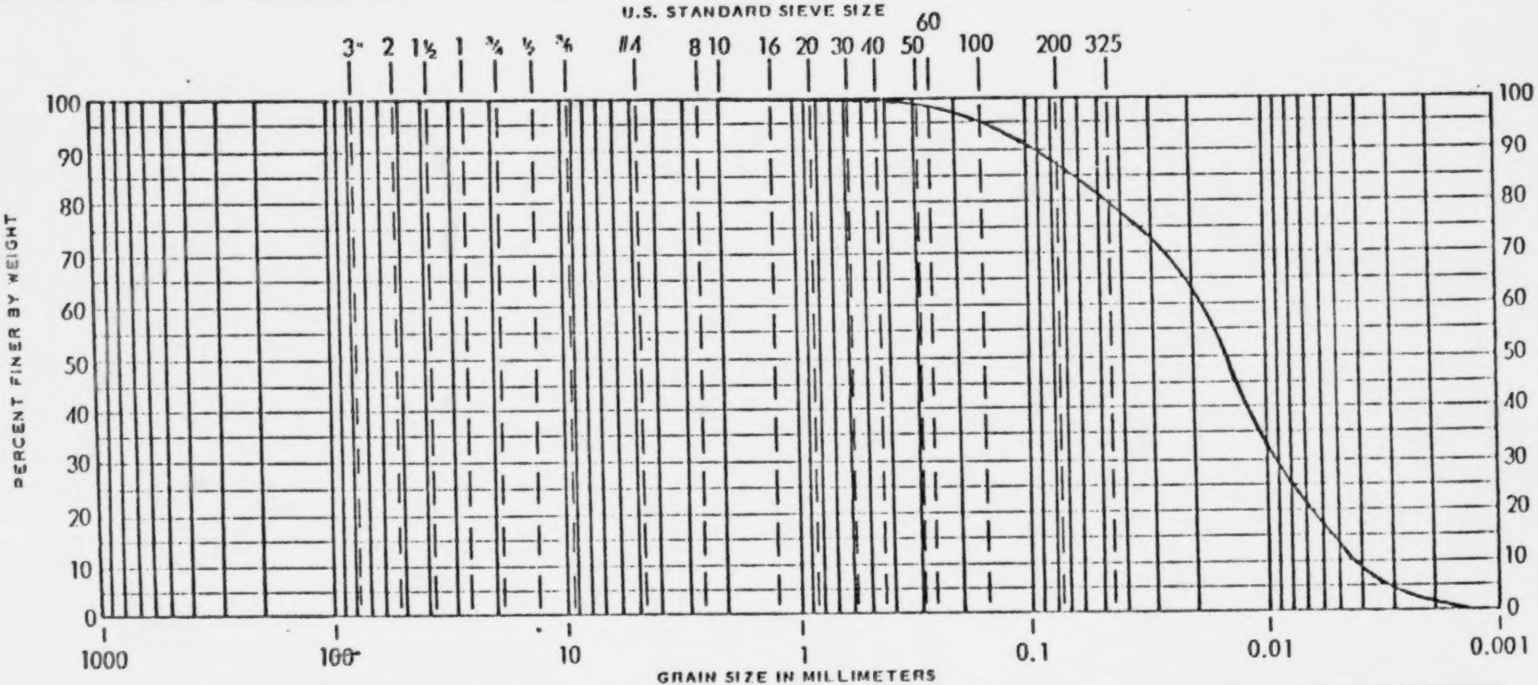

COBBLES	GRAVEL 0%		SAND 13%			SILT 72%	CLAY 15%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-ITPI
SAMPLE NO. 5C
DEPTH 1.5' - 3.0'
CLASSIFICATION "ML"
Sandy "SILT"

NATURAL % MOISTURE Saturated
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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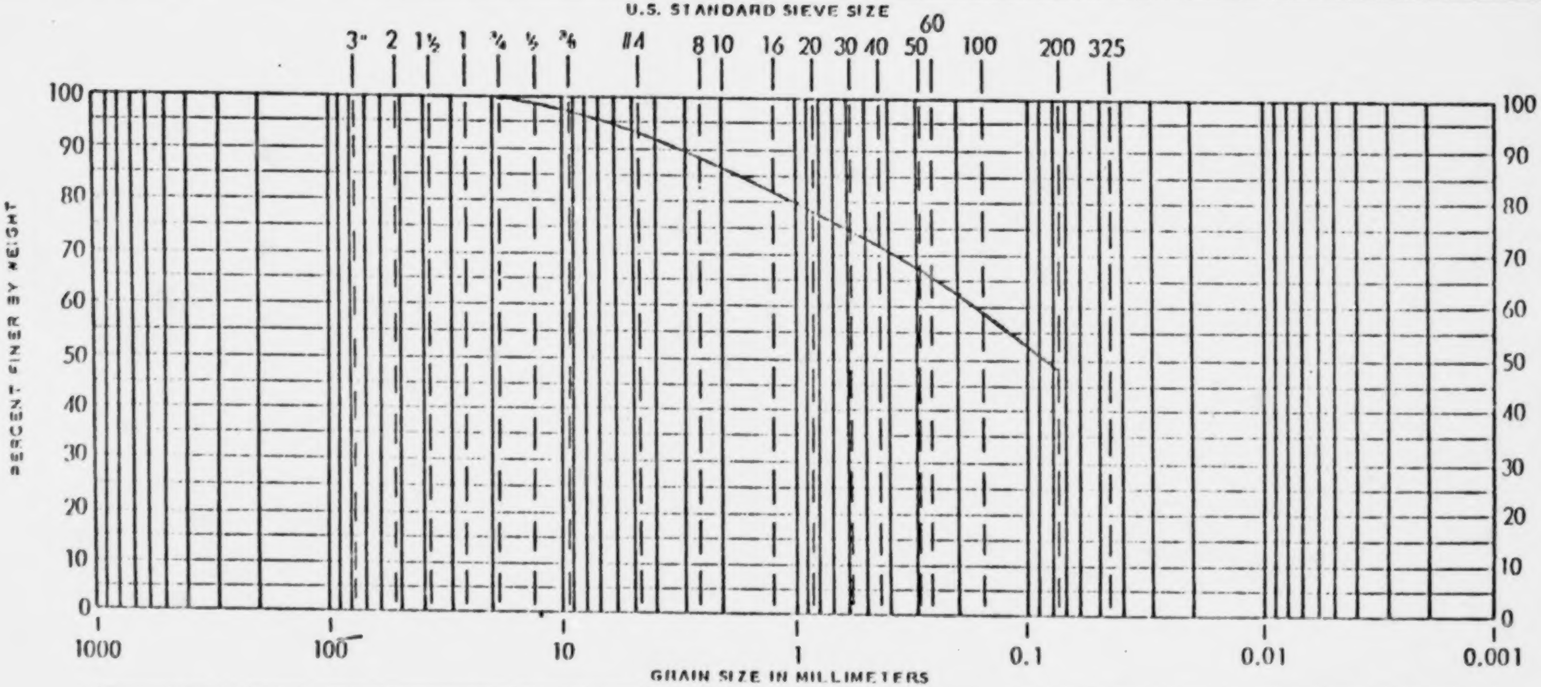

COBBLES	GRAVEL 7%		SAND 44%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	49%	

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-1
SAMPLE NO. 5A
DEPTH 30.0' - 31.5'
CLASSIFICATION "SM"
Silty Sand

NATURAL % MOISTURE Saturated
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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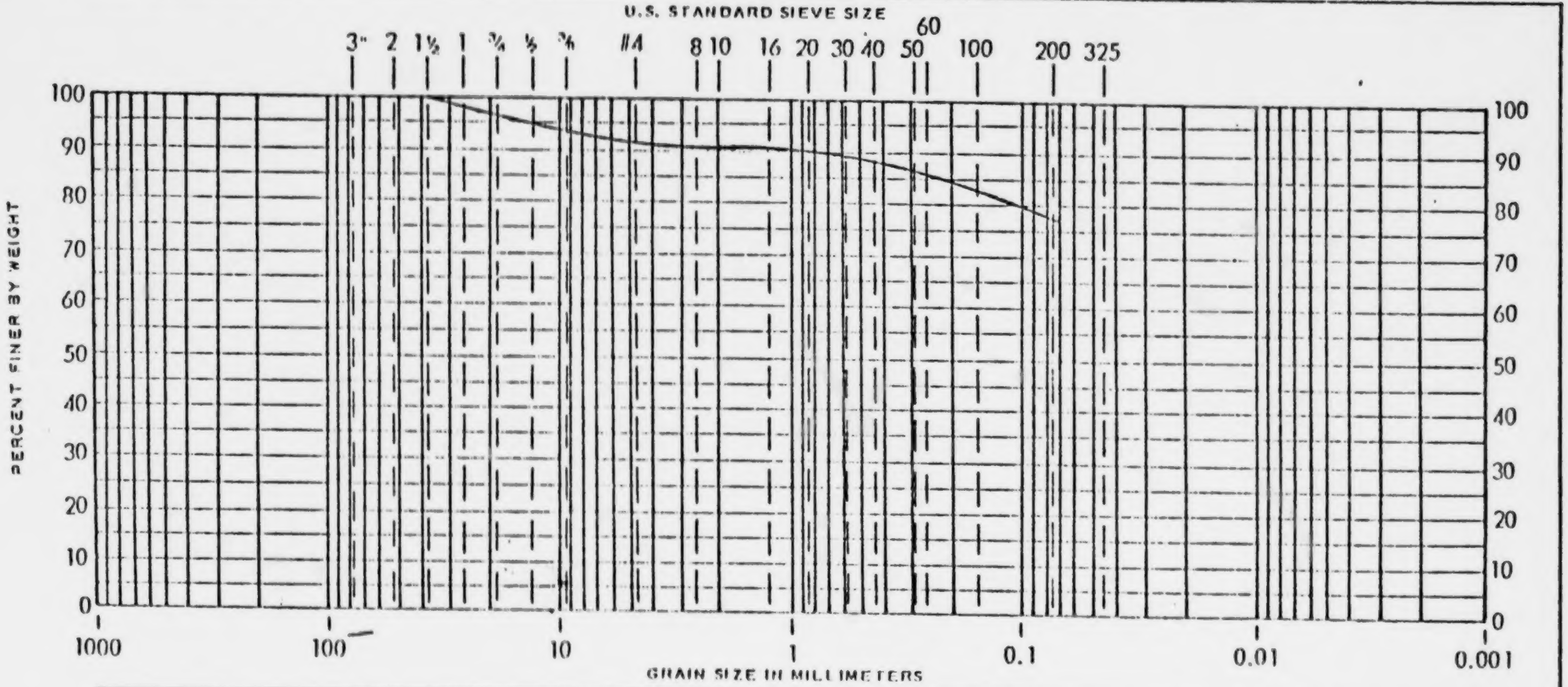

COBBLES	GRAVEL 9%		SAND 14%			SILT 77%	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT	Arthur D. Little Allen Disposal Site
BORING NO.	3-1
SAMPLE NO.	9A
DEPTH	55.0' - 56.5'
CLASSIFICATION	"ML" Sandy Silt

NATURAL % MOISTURE	Saturated
LIQUID LIMIT	Visually
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Gray
REMARKS	"U.S.C.S."

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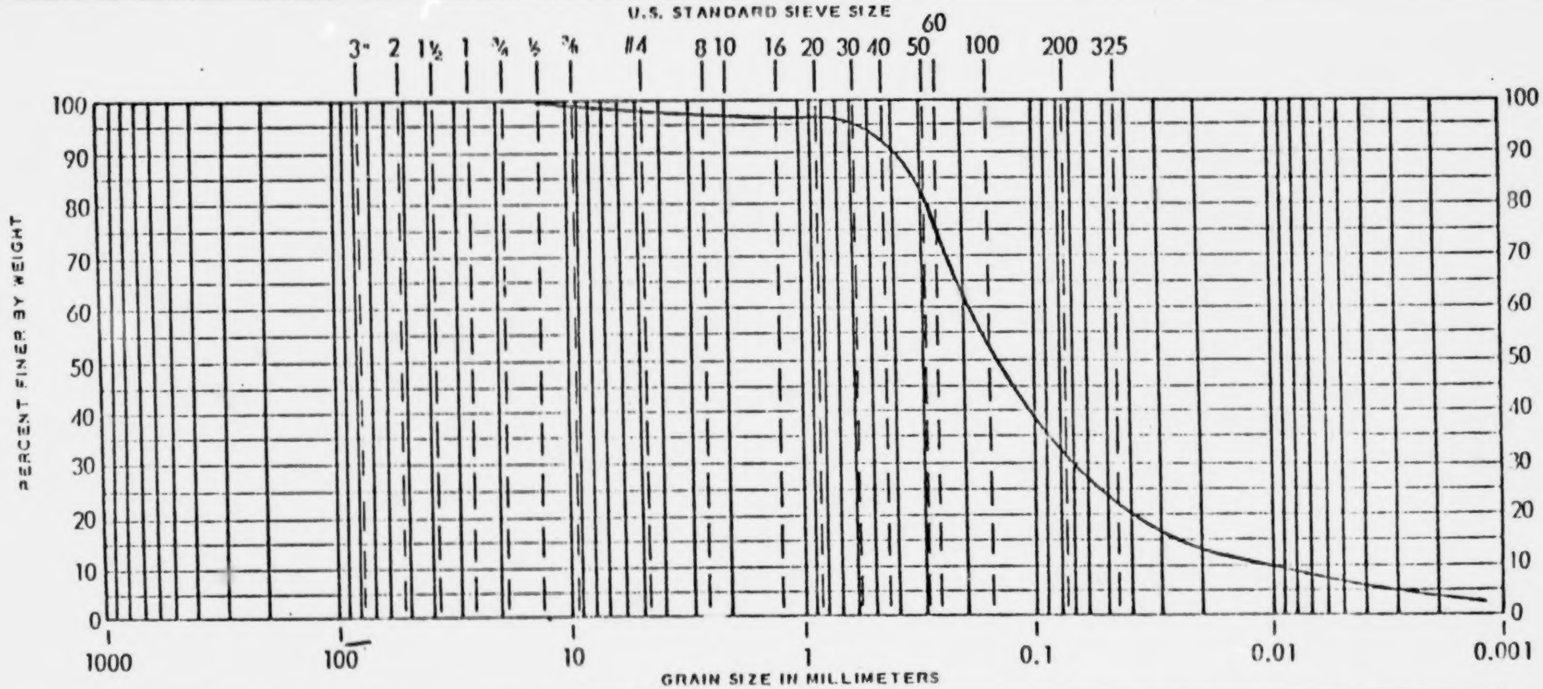

COBBLES	GRAVEL 2%		SAND 65%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	15%	9%

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-2
SAMPLE NO. 4A
DEPTH 18.0' - 20.0'
CLASSIFICATION "SM".
Silty sand

NATURAL % MOISTURE 43.71
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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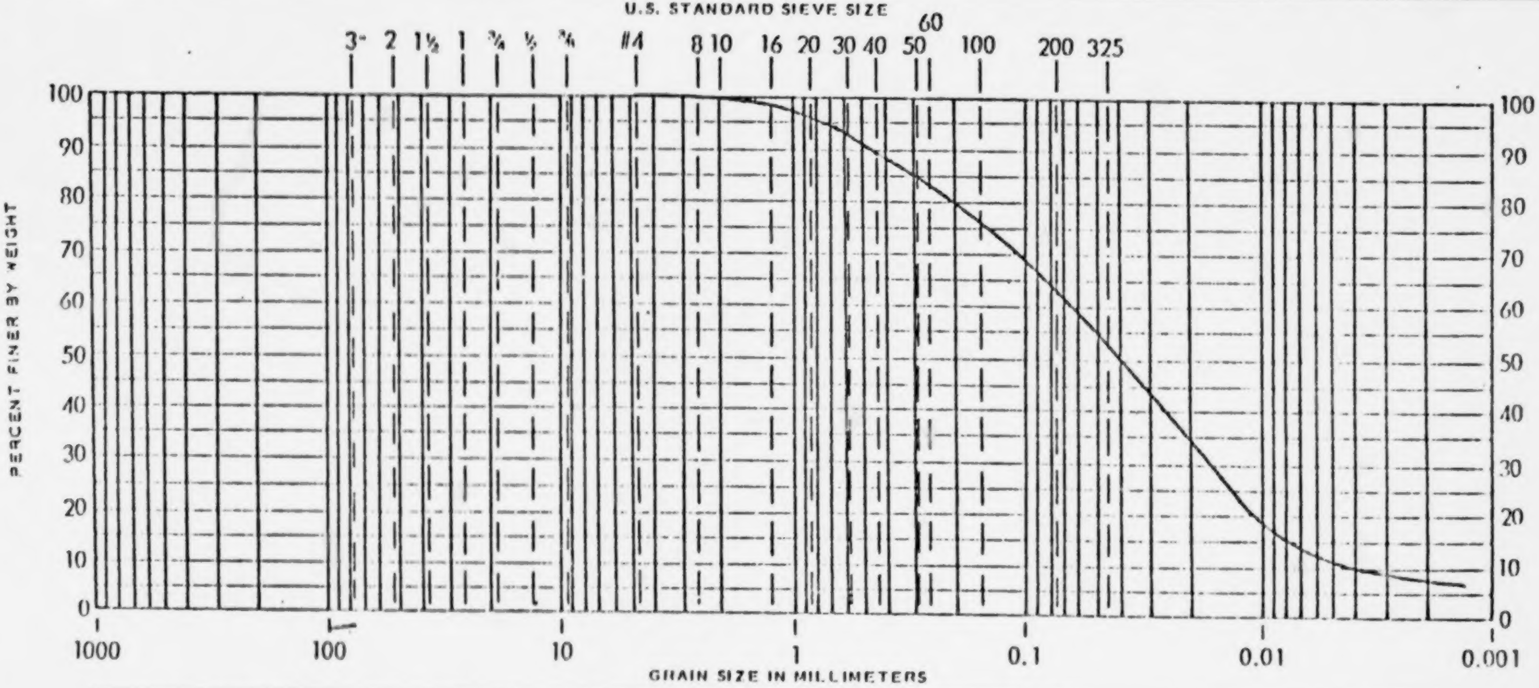

COBBLES	GRAVEL 0		SAND 37%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	52%	11%

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-2
SAMPLE NO. 7A
DEPTH 36.6' - 38.0'
CLASSIFICATION "ML"
Sandy, Silt

NATURAL % MOISTURE 49.5
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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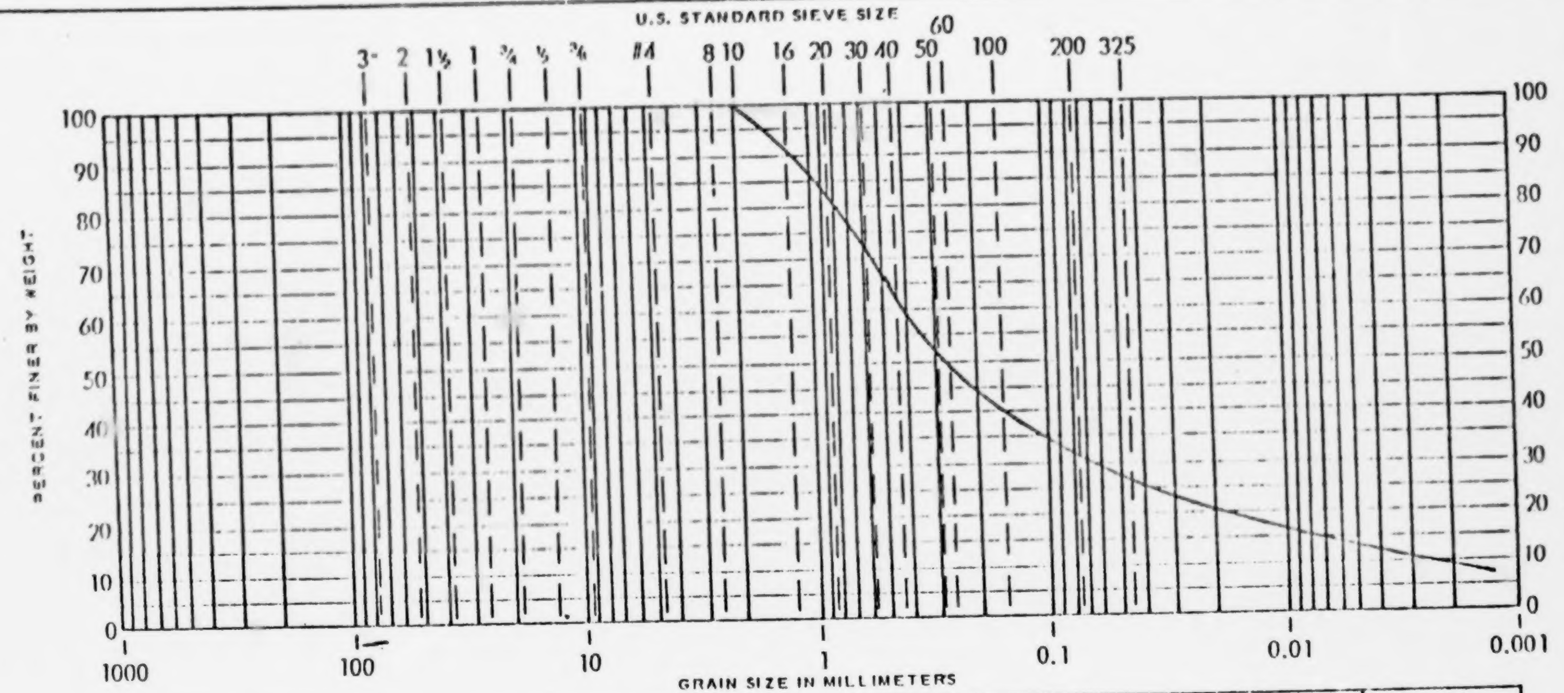

COBBLES	GRAVEL 0%		SAND 69%			SILT 8%	CLAY 28%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT	Arthur D. Little Allen Disposal Site
BORING NO.	3-2
SAMPLE NO.	13A
DEPTH	52.0' - 54.0'
CLASSIFICATION	"SM" Silty Sand

NATURAL % MOISTURE	22.21
LIQUID LIMIT	39
PLASTIC LIMIT	26
PLASTICITY INDEX	13
COLOR	Brown and Gray
REMARKS	"U.S.C.S."

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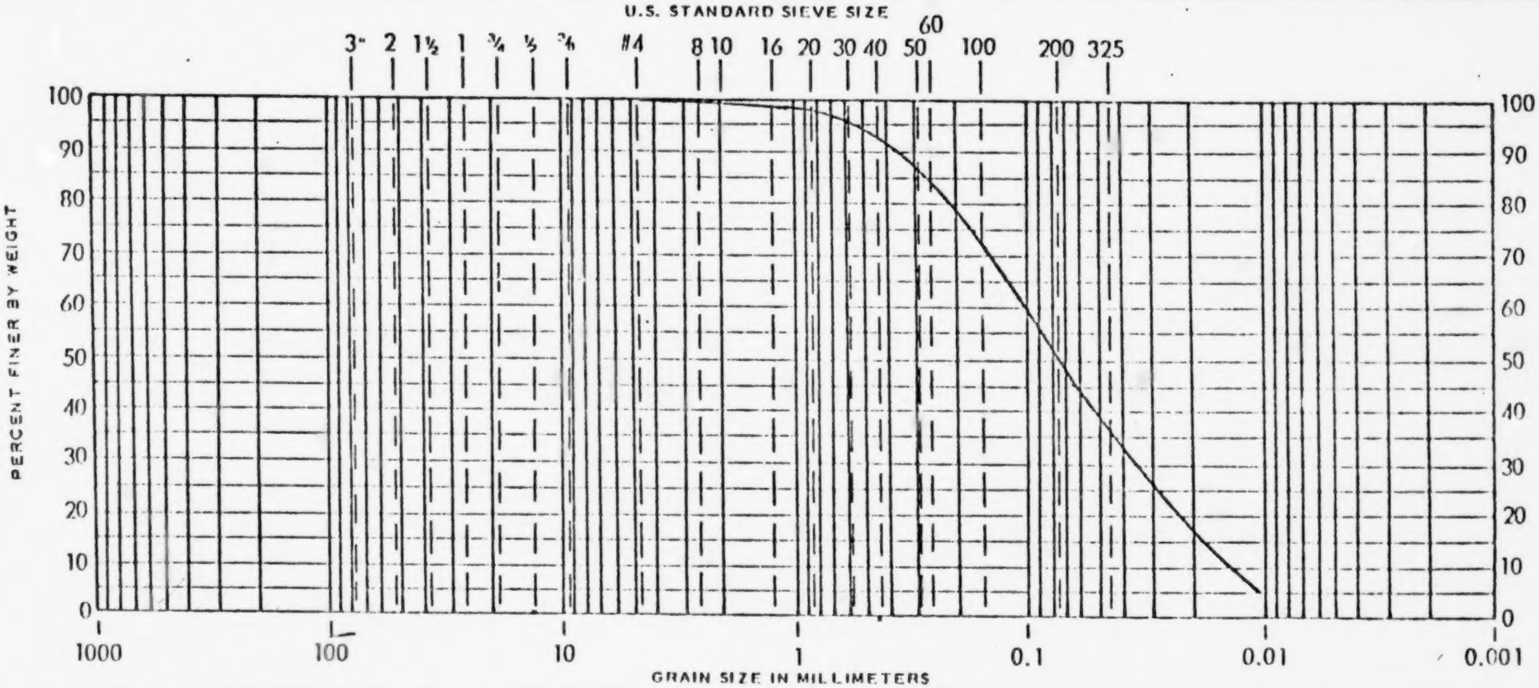

COBBLES	GRAVEL 0%		SAND 49%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	51%	0%

PROJECT	Arthur D. Little Allen Disposal Site	NATURAL % MOISTURE	51.1
BORING NO.	3-3	LIQUID LIMIT	Tested
SAMPLE NO.	1B	PLASTIC LIMIT	Non
DEPTH	4.0' - 5.5'	PLASTICITY INDEX	Plastic
CLASSIFICATION	"ML". Sandy Silt	COLOR	Gray
		REMARKS	"U.S.C.S."

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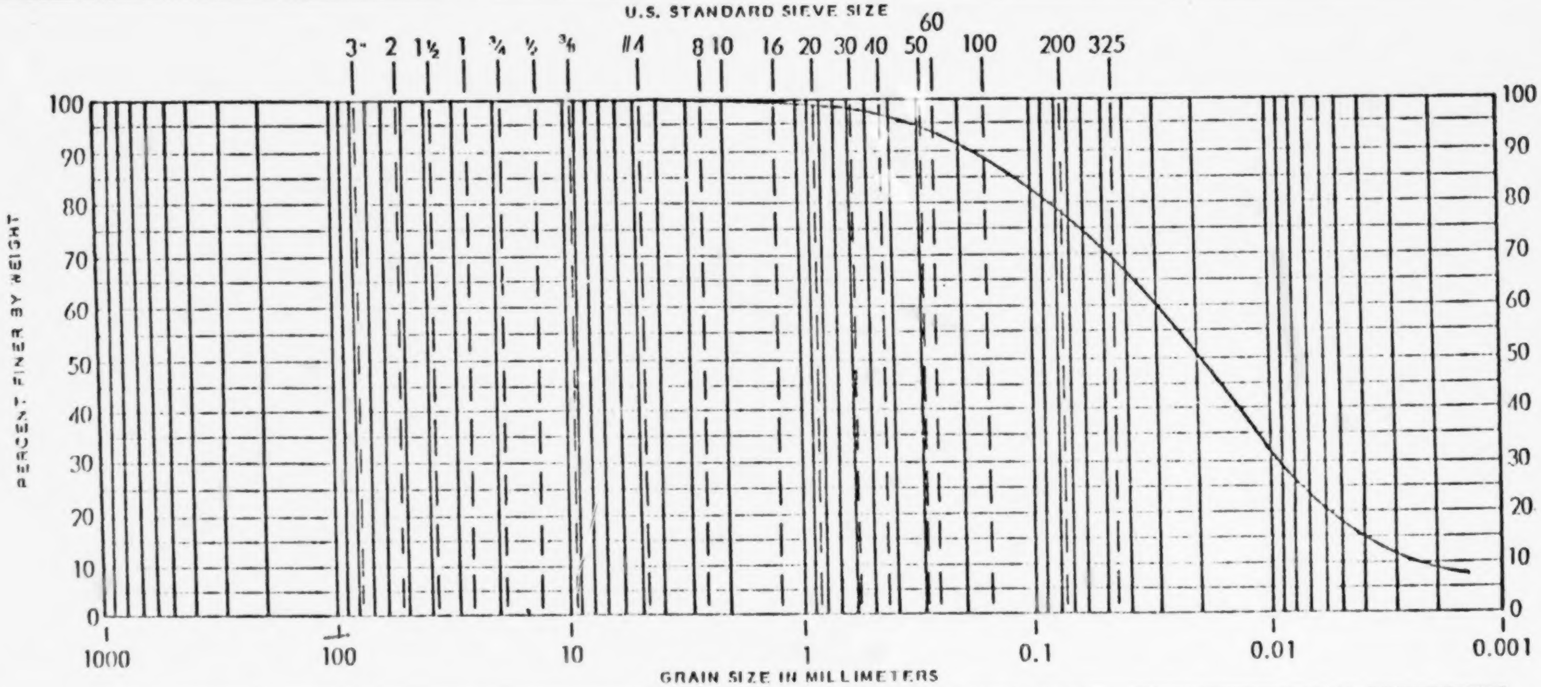

COBBLES	GRAVEL 0		SAND 23%			SILT 60%	CLAY 17%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-3
SAMPLE NO. 2A
DEPTH 12.0' - 14.0'
CLASSIFICATION "ML"
Sandy, Silt

NATURAL % MOISTURE 35.29
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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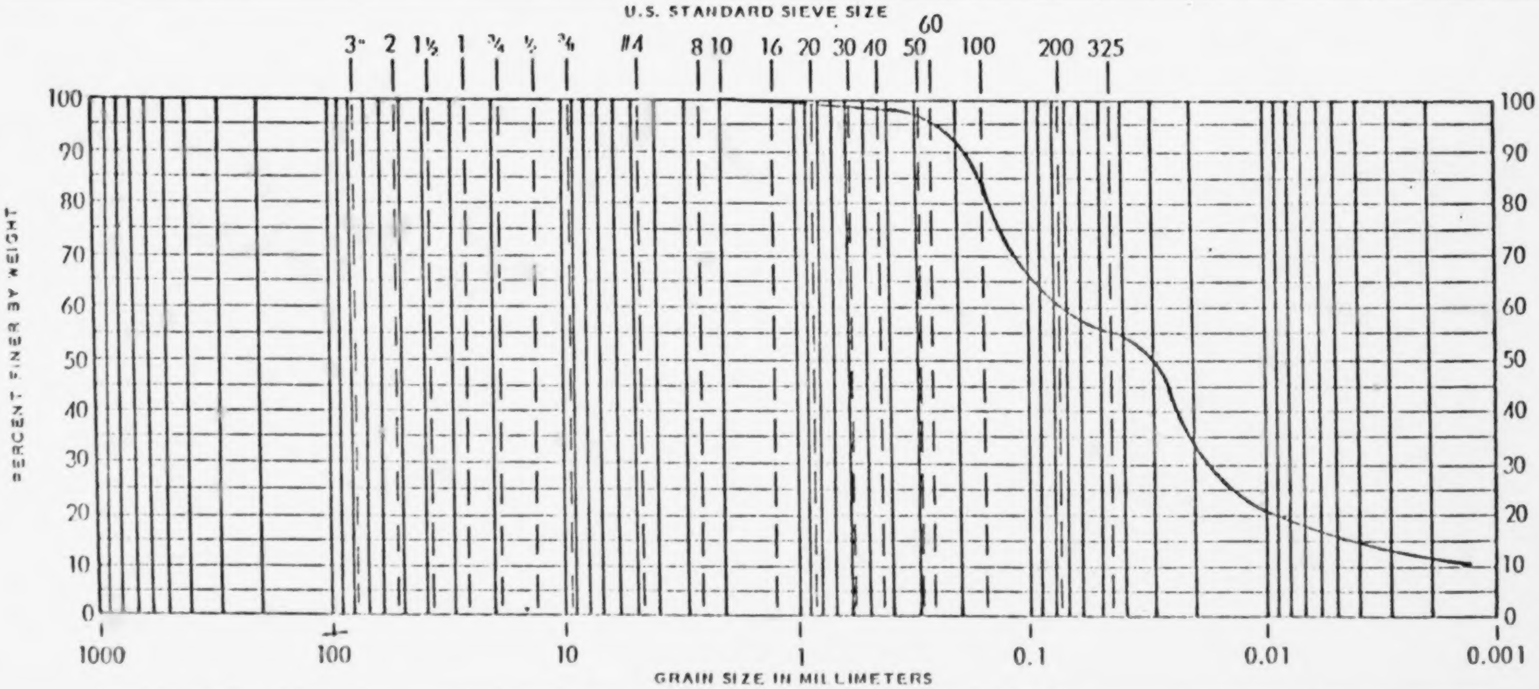

COBBLES	GRAVEL 0		SAND 41%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	43%	16%

PROJECT	Arthur D. Little Allen Disposal Site
BORING NO.	3-3
SAMPLE NO.	6A
DEPTH	28.0' - 30.0'
CLASSIFICATION	"ML" Sandy, Silt

NATURAL % MOISTURE	49.43
LIQUID LIMIT	Tested
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Reddish Brown
REMARKS	"U.S.C.S."

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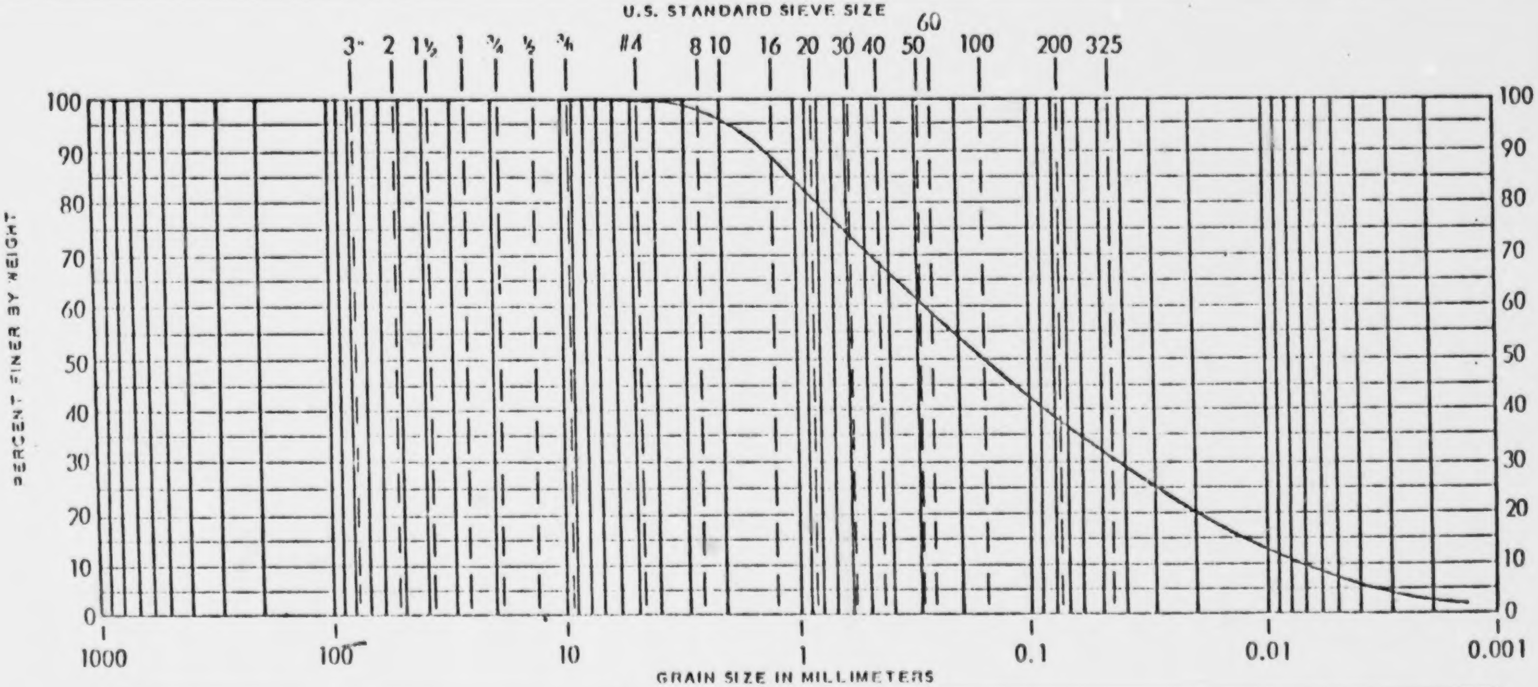

COBBLES	GRAVEL 1%		SAND 61%			SILT 31%	CLAY 7%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-3
SAMPLE NO. 8A
DEPTH 32.0' - 34.0'
CLASSIFICATION "SM"
Silty Sand

NATURAL % MOISTURE 30.29
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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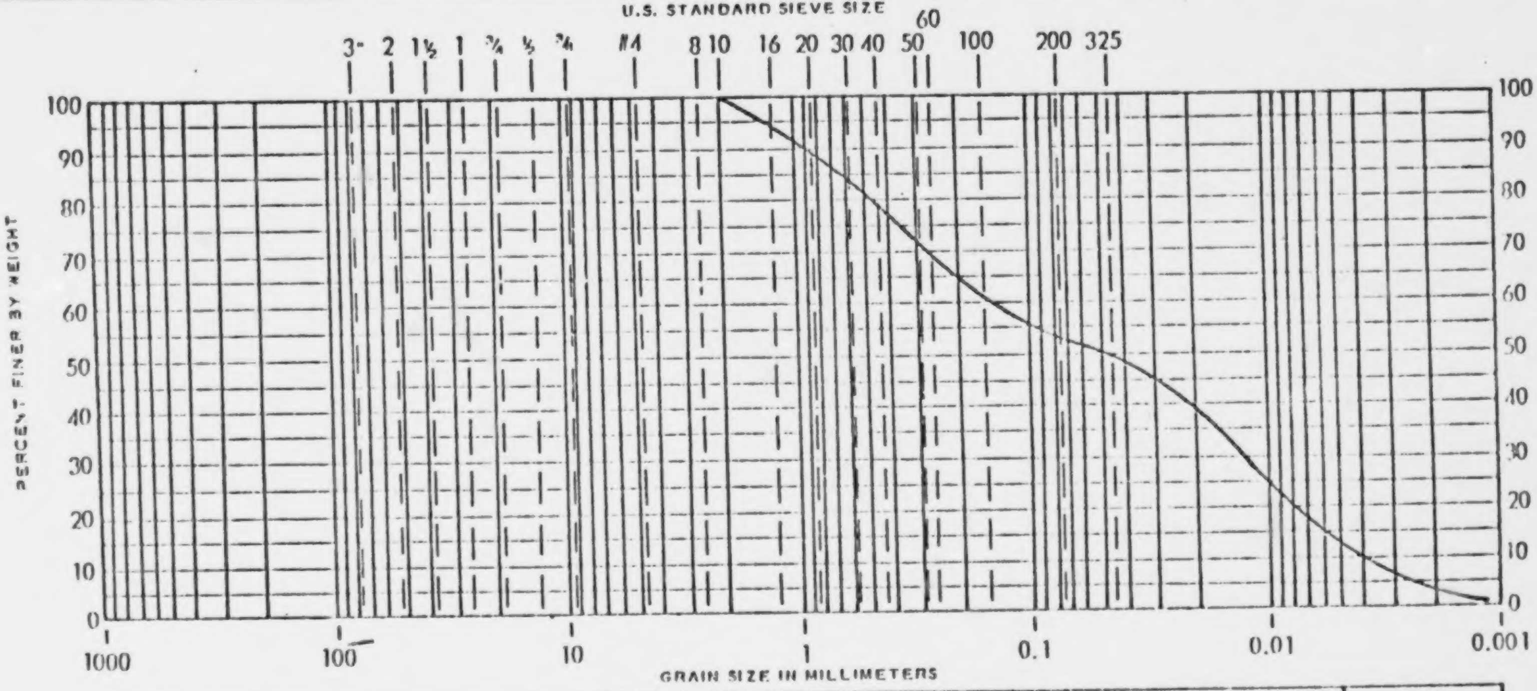

COBBLES	GRAVEL 0		SAND 47%			SILT 40%	CLAY 13%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-5
SAMPLE NO. 5A
DEPTH 19.0' - 21.0'
CLASSIFICATION "ML".
Silty, fine sand

NATURAL % MOISTURE 28.1
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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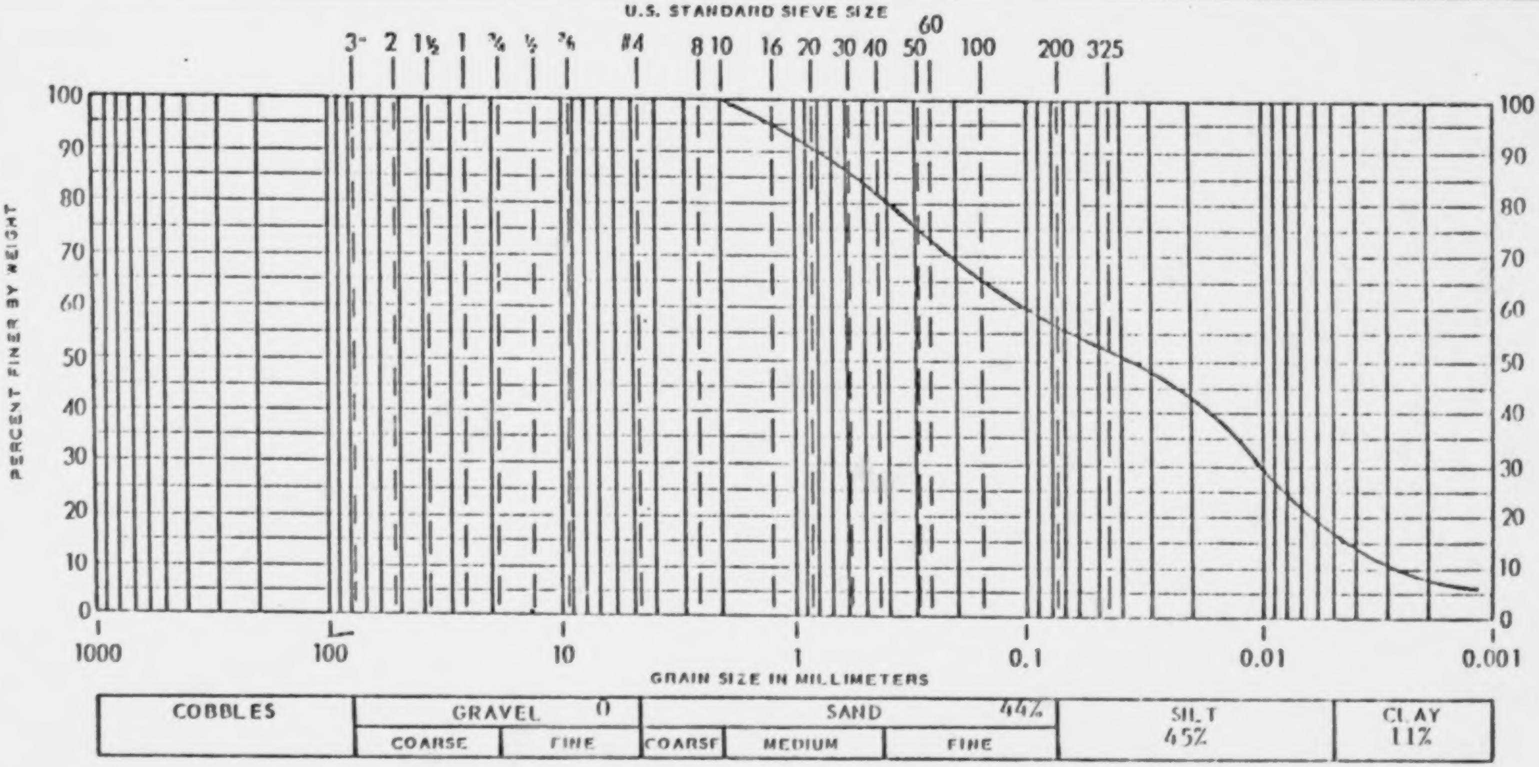

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-6
SAMPLE NO. 7A
DEPTH 12.0' - 14.0'
CLASSIFICATION "ML"
Sandy Silt

NATURAL % MOISTURE 30.68
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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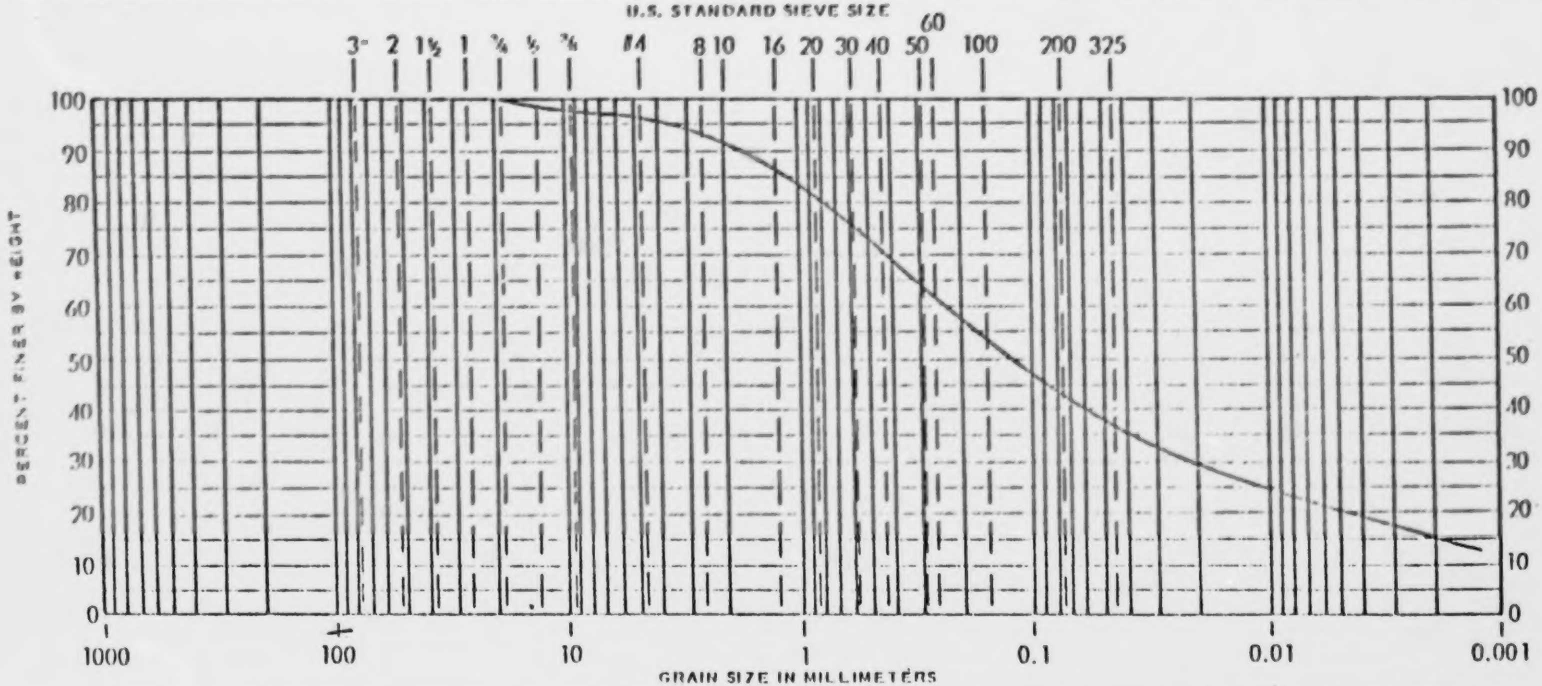

COBBLES	GRAVEL 40%		SAND 53%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	24%	19%

PROJECT	Arthur D. Little Allen Disposal Site
BORING NO.	3-6
SAMPLE NO.	16A
DEPTH	32.5' - 34.5'
CLASSIFICATION	"SM" Silty Sand

NATURAL % MOISTURE	21.4
LIQUID LIMIT	34
PLASTIC LIMIT	26
PLASTICITY INDEX	8
COLOR	Brown & Gray
REMARKS	"U.S.C.S."

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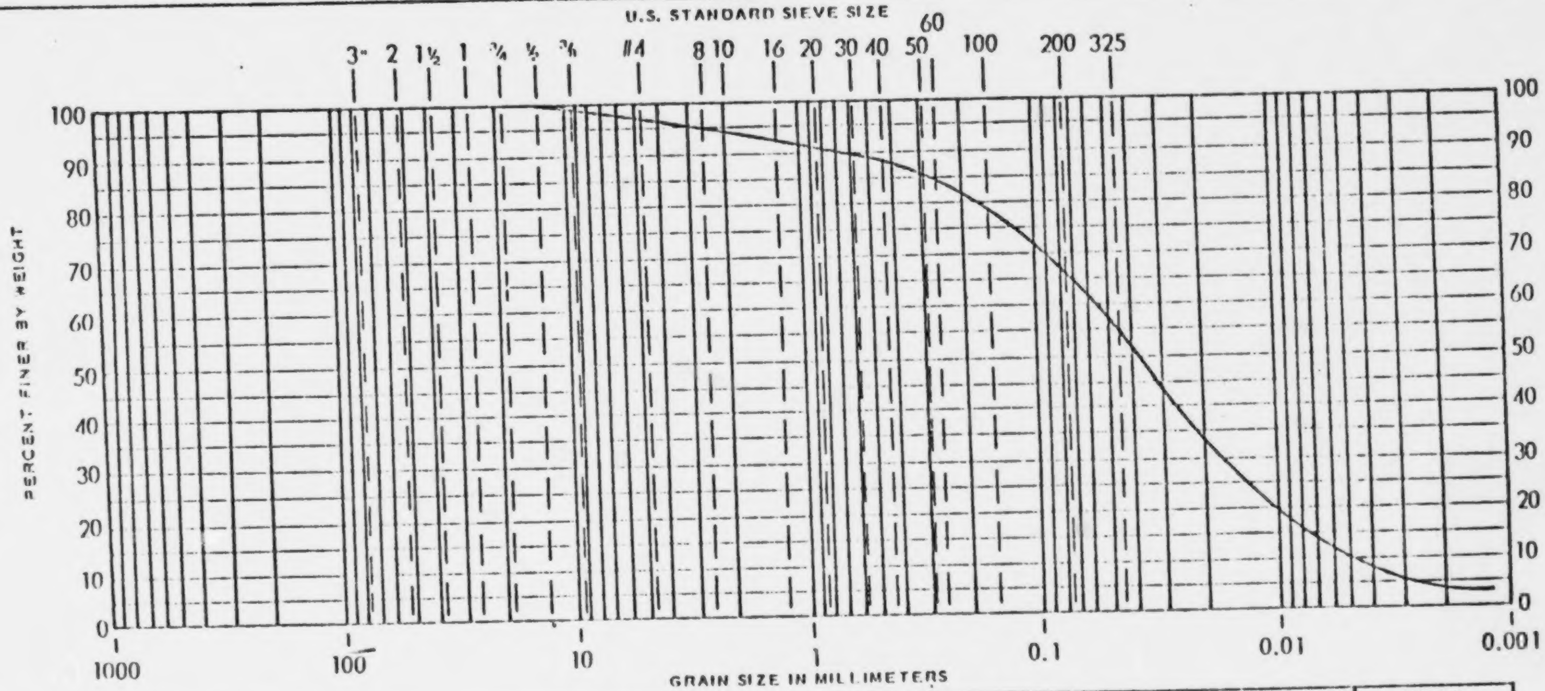
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 3%		SAND 31%			SILT 59%	CLAY 7%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-6
SAMPLE NO. 21A
DEPTH 54.5' - 56.0'
CLASSIFICATION "ML"
Sandy, Silt

NATURAL % MOISTURE 16.16
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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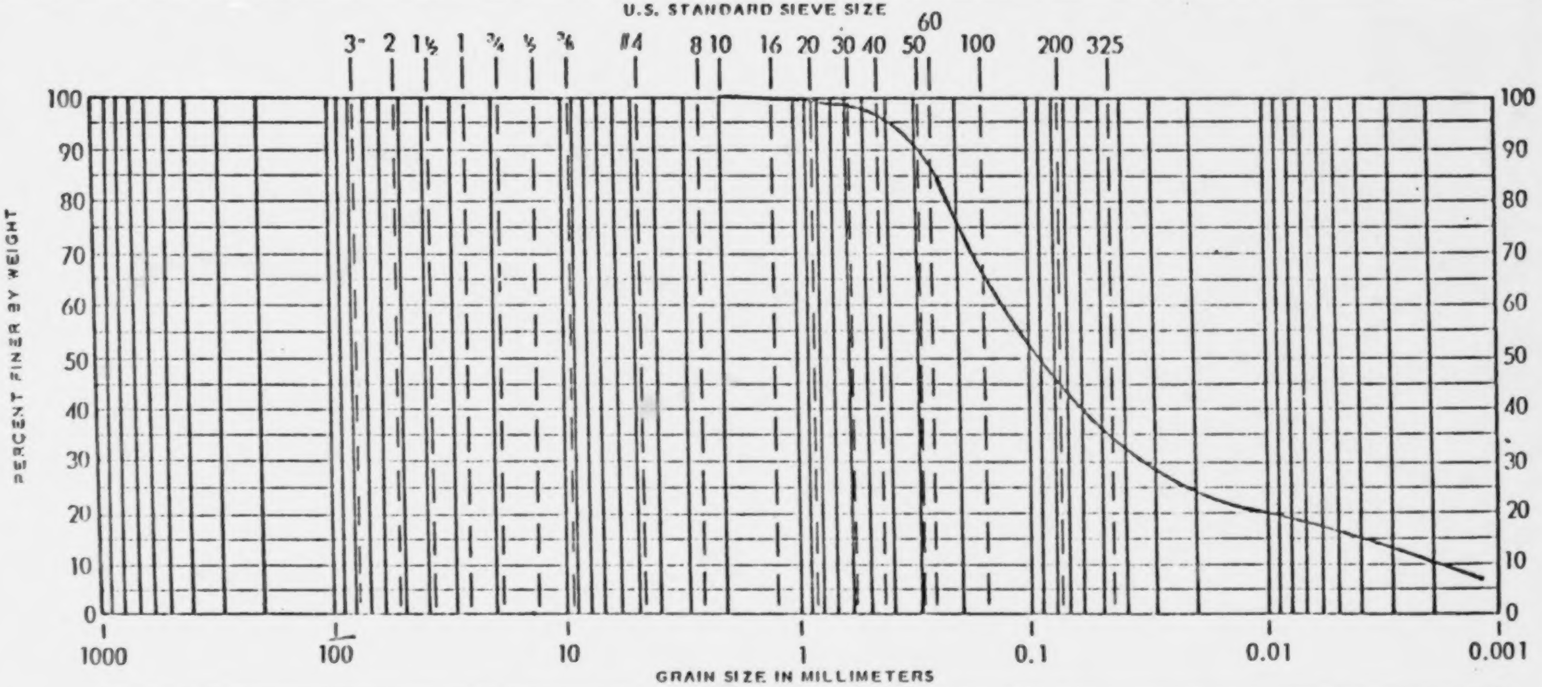

COBBLES	GRAVEL 0		SAND 56%			SILT 27%	CLAY 17%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-7
SAMPLE NO. 4A
DEPTH 14.0' - 16.0'
CLASSIFICATION "SM"
Silty, Sand

NATURAL % MOISTURE 28.5
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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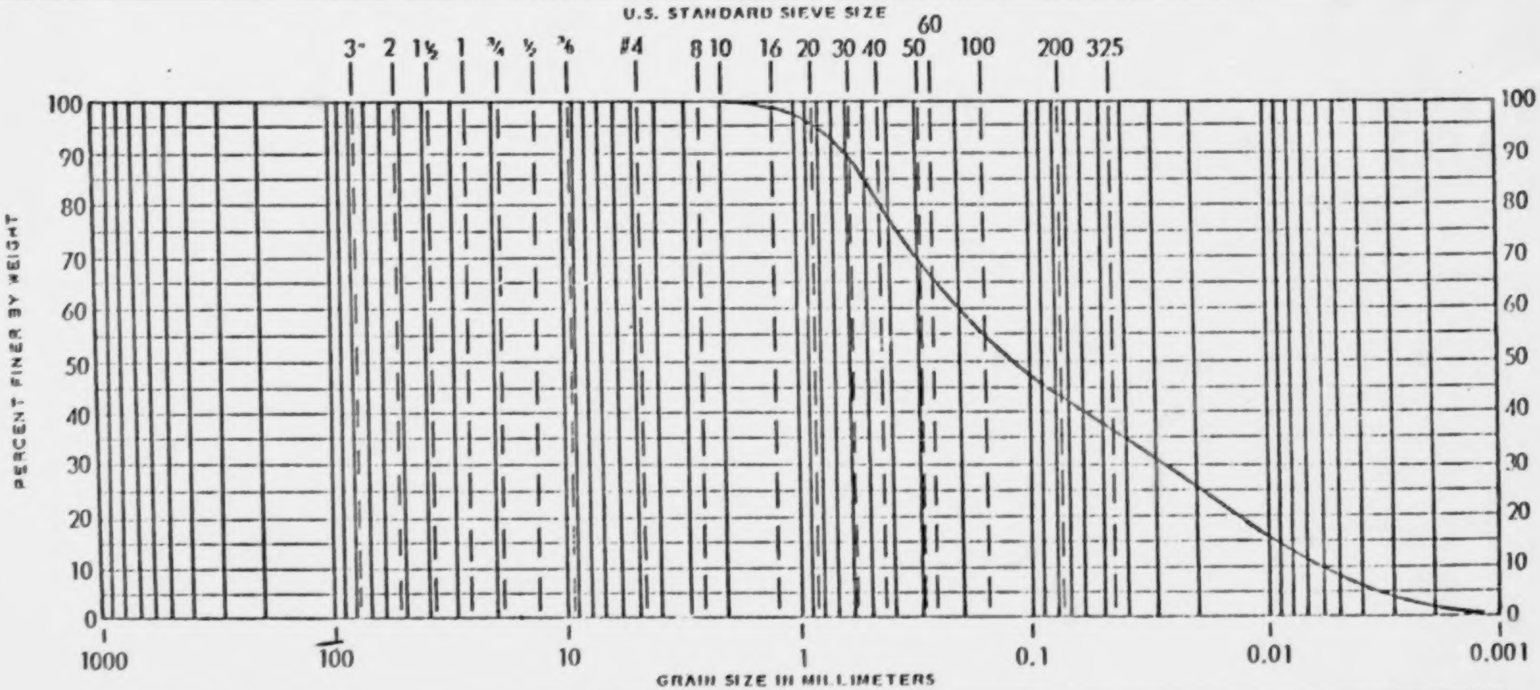


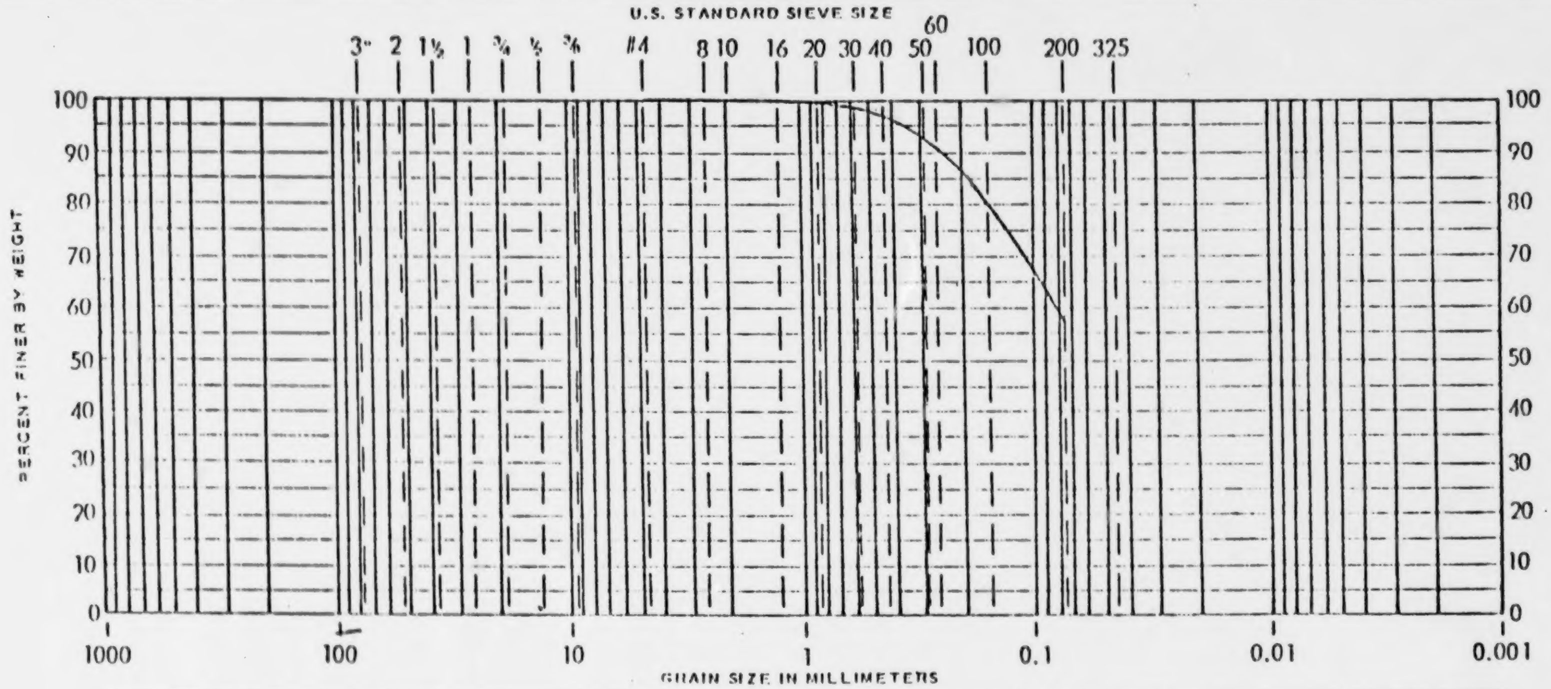
COBBLES	GRAVEL 0%		SAND 57%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	35%	8%

PROJECT Arthur D. Little
Allen Disposal Site
BORING NO. 3-8
SAMPLE NO. 6A
DEPTH 24.0' - 26.0'
CLASSIFICATION "SM"
Silty Sand

NATURAL % MOISTURE 34.7
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 0		SAND 43%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	57%	

PROJECT Arthur D. Little
Allen Disposal Site

SAMPLE NO. Bag Sample

CLASSIFICATION "ML"
Sandy silt

LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

LABORATORY SUMMARY SHEET

Arthur D. Little, Allen Disposal Site

Page 1 of 5

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
3-1	1A						39.3			
	2A						37.7			
	3A						Saturated			
	4A						Saturated			
	5A						Saturated			
	6A						Saturated			
	7A						Saturated			
	8A						Saturated			
	9A						Saturated			
	10A						37.6			
	10AA						26.3			
3-2	2A-1						32.9			
	3A-1						Saturated			
	4A-1						45.4			
	5A-1						50.2			
	7A-1						46.8			
	8A-1						51.8			
	9A-1						43.3			
	13A-1						23.3			
3-3	1A-1						40.6			
	2A-1						Saturated			
	3A-1						Saturated			
	4A-1						47.5			
	5A-1						42.3			
	5C-1A						Saturated			
	5C-1						17.5			
	7A-1						25.9			
	8A-1						29.3			

LABORATORY SUMMARY SHEET

Arthur D. Little, Allen Disposal Site

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
3-4	1A						38.1			
	2A						24.1			
	3A						31.5			
	4A						31.0			
	5A						25.5			
	6A						23.4			
	7A						24.1			
	8A						15.0			
	1C						19.5			
	9A-1						20.5			
	2C						26.9			
3-4A	1C						20.7			
3-5	1A						24.3			
	2A						23.3			
	3A						23.6			
	4A						26.9			
	5A						29.0			
	6A						29.7			
	7A						30.6			
	8A						27.3			
	9A						25.4			
	1C						28.2			
	10A						30.4			
	10AA						23.7			
	11A						36.7			

LABORATORY SUMMARY SHEET

Arthur D. Little, Allen Disposal Site

Page 3 of 5

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
3-6	1A						21.3			
	2A						25.2			
	3A						22.4			
	4A						25.1			
	5A						24.8			
	6A						27.0			
	7A						30.9			
	8A						27.5			
	9A						26.9			
	1C						33.6			
	10A						25.9			
	11A						29.6			
	12A						38.8			
	13A						33.6			
	14A						35.0			
	15A-1						30.9			
	15A-2						25.1			
	16A						20.7			
	17A						22.0			
	3C						22.4			
	18A						16.5			
	19A						19.9			
	21A						23.3			
3-6A	1C						45.0			
	2C						34.8			
3-6C	1A-1						10.9			
	1C						34.9			

LABORATORY SUMMARY SHEET

Arthur D. Little, Allen Disposal Site

Page 4 of 5

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
3-7	1A						17.9			
	2A						25.3			
	3A						24.0			
	4A						29.5			
	5A-A						24.7			
	5A-B						29.1			
	1C						13.5			
	6A						14.2			
3-7A	1B						23.1			
	2B						28.5			
3-8	1A						20.3			
	2A						23.2			
	3A						14.9			
	4A						45.2			
	5A						42.6			
	6A						36.4			
	7A						37.1			
3-8A	1A						28.9			
	2A						32.4			
	3A						26.9			
	4A						31.4			
3-9	1A						25.8			
	2A						27.3			
	3A						23.6			
	4A						32.0			
	5A						33.9			
	6A						54.8			

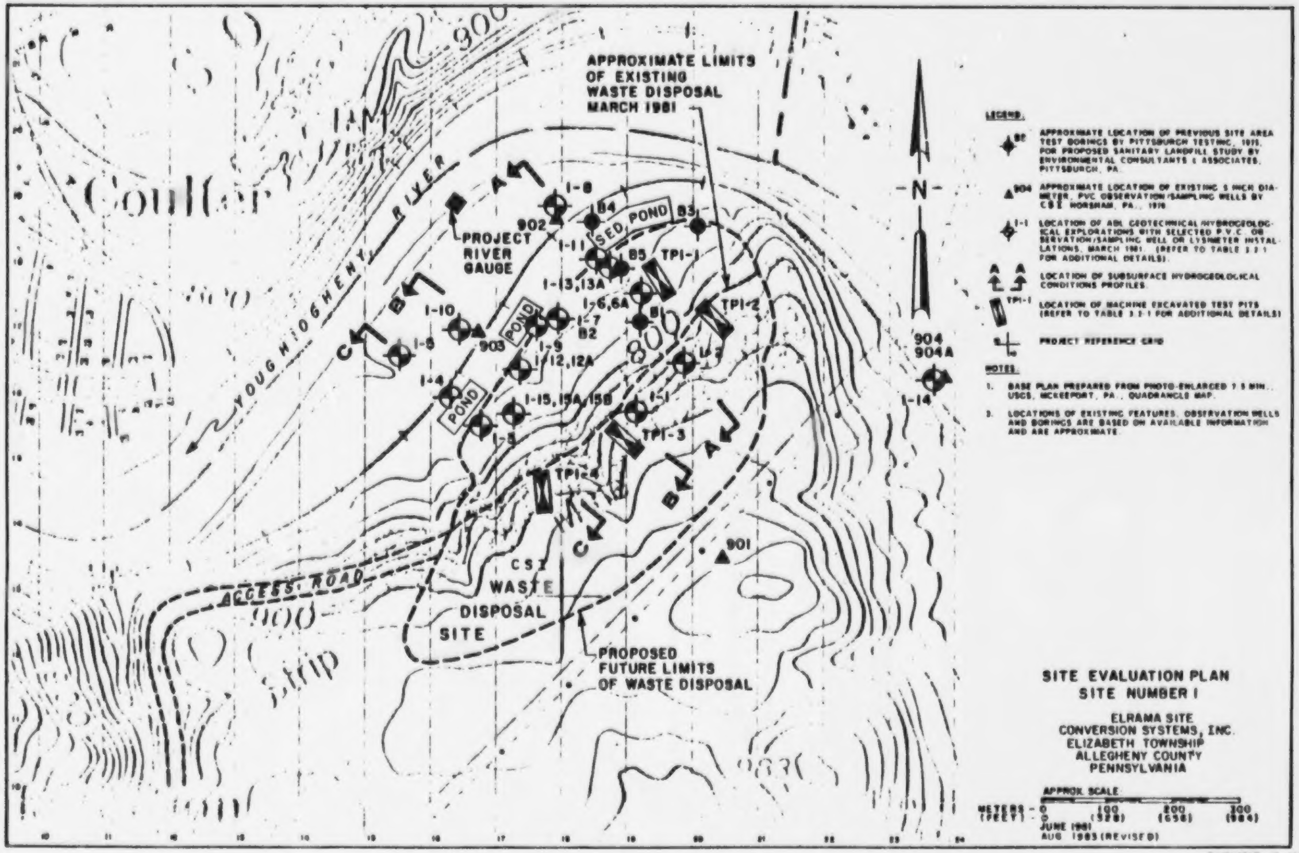
LABORATORY SUMMARY SHEET

Arthur D. Little, Allen Disposal Site

Page 5 of 5

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
3-9A	1C						42.1			
	2A						40.9			
	2C						33.3			
3-4B	1A						18.8			
	2A						14.1			
	3A						24.4			
	4A						24.6			
	1C						16.6			
	5A						14.8			

Elrama Duquesne Light and CSI


APPROXIMATE LIMITS OF EXISTING WASTE DISPOSAL MARCH 1981
N
Coulter
900
800
YOUGHIOGHENY RIVER
PROJECT RIVER GAUGE
A
B
C
SED. POND
POND
POND
B4
B3
B5
B1
B2
902
903
901
904
904A
I-8
I-11
I-13,13A
I-6,6A
I-7
I-9
I-12,12A
I-10
I-5
I-4
I-3
I-15,15A
15B
I-1
I-2
I-14
TPI-1
TPI-2
TPI-3
TPI-4
ACCESS ROAD
CSI WASTE DISPOSAL SITE
PROPOSED FUTURE LIMITS OF WASTE DISPOSAL
Strip

LEGEND:

APPROXIMATE LOCATION OF PREVIOUS SITE AREA TEST BORINGS BY PITTSBURGH TESTING, 1975, FOR PROPOSED SANITARY LANDFILL STUDY BY ENVIRONMENTAL CONSULTANTS & ASSOCIATES, PITTSBURGH, PA.

APPROXIMATE LOCATION OF EXISTING 5 INCH DIAMETER, PVC OBSERVATION/SAMPLING WELLS BY CSI HORSHAM, PA., 1978

LOCATION OF ABL GEOTECHNICAL/HYDROGEOLOGICAL EXPLORATIONS WITH SELECTED P.V.C. OBSERVATION/SAMPLING WELL OR LYSIMETER INSTALLATIONS, MARCH 1981. (REFER TO TABLE 3.2-1 FOR ADDITIONAL DETAILS)

LOCATION OF SUBSURFACE HYDROGEOLOGICAL CONDITIONS PROFILES

LOCATION OF MACHINE EXCAVATED TEST PITS (REFER TO TABLE 3.2-1 FOR ADDITIONAL DETAILS)

PROJECT REFERENCE GRID

NOTES:

1. BASE PLAN PREPARED FROM PHOTO-ENLARGED 7.5 MIN., USGS, MCKEESPORT, PA., QUADRANGLE MAP.
2. LOCATIONS OF EXISTING FEATURES, OBSERVATION WELLS AND BORINGS ARE BASED ON AVAILABLE INFORMATION AND ARE APPROXIMATE.

SITE EVALUATION PLAN
SITE NUMBER 1

ELRAMA SITE
CONVERSION SYSTEMS, INC.
ELIZABETH TOWNSHIP
ALLEGHENY COUNTY
PENNSYLVANIA

APPROX. SCALE
METERS - 0 100 200 300
(FEET) - 0 (328) (656) (984)
JUNE 1981
AUG 1983 (REVISED)

FIGURE 5.12

UNIVERSITY OF LOUISVILLE
LOUISVILLE, KENTUCKY 40292

SPEED SCIENTIFIC SCHOOL
JAMES BRECKENRIDGE SPEED FOUNDATION
DEPARTMENT OF CIVIL ENGINEERING

September 3, 1981

MEMO TO: C. J. Santhanam, ADL

FROM. .: C. R. Ullrich, UL CR Ullrich

SUBJECT: QA/QC Physical Property Tests

Please find attached a summary of QA/QC tests performed on samples from Elrama. Results of tests performed on samples from Allen will follow shortly. Samples from Sherco have been received courtesy of Barry Thacker. Dave Johnson samples have not been received yet, but we understand they are being forwarded to us by Bowser-Morner.

SUMMARY OF RESULTS

QA/QC PHYSICAL PROPERTY TESTS

ELRAMA STATION

Boring No.: 1-15A

Sample No.: U1

Depth: 4.0' - 6.0'

Date of Sampling: 3/14/81

*Results of permeability tests on remolded, compacted samples:

Depth Interval (ft.)	Material	Water Content (%)	Moist Density (pcf)	Dry Density (pcf)	Coefficient of Permeability (cm/sec)
4.0-4.5	sludge	21.0	121.7	101.1	4.19×10^{-7}
4.5-5.0	ash	21.6	81.1	66.8	3.38×10^{-4}
5.0-5.5	ash	21.9	72.4	59.3	5.58×10^{-4}
5.5-6.0	sludge	49.7	94.2	63.0	9.26×10^{-6}

*Results of unconfined compression test on undisturbed sample of sludge from 4.0'-4.5':

Unconfined compressive strength: 662 psf

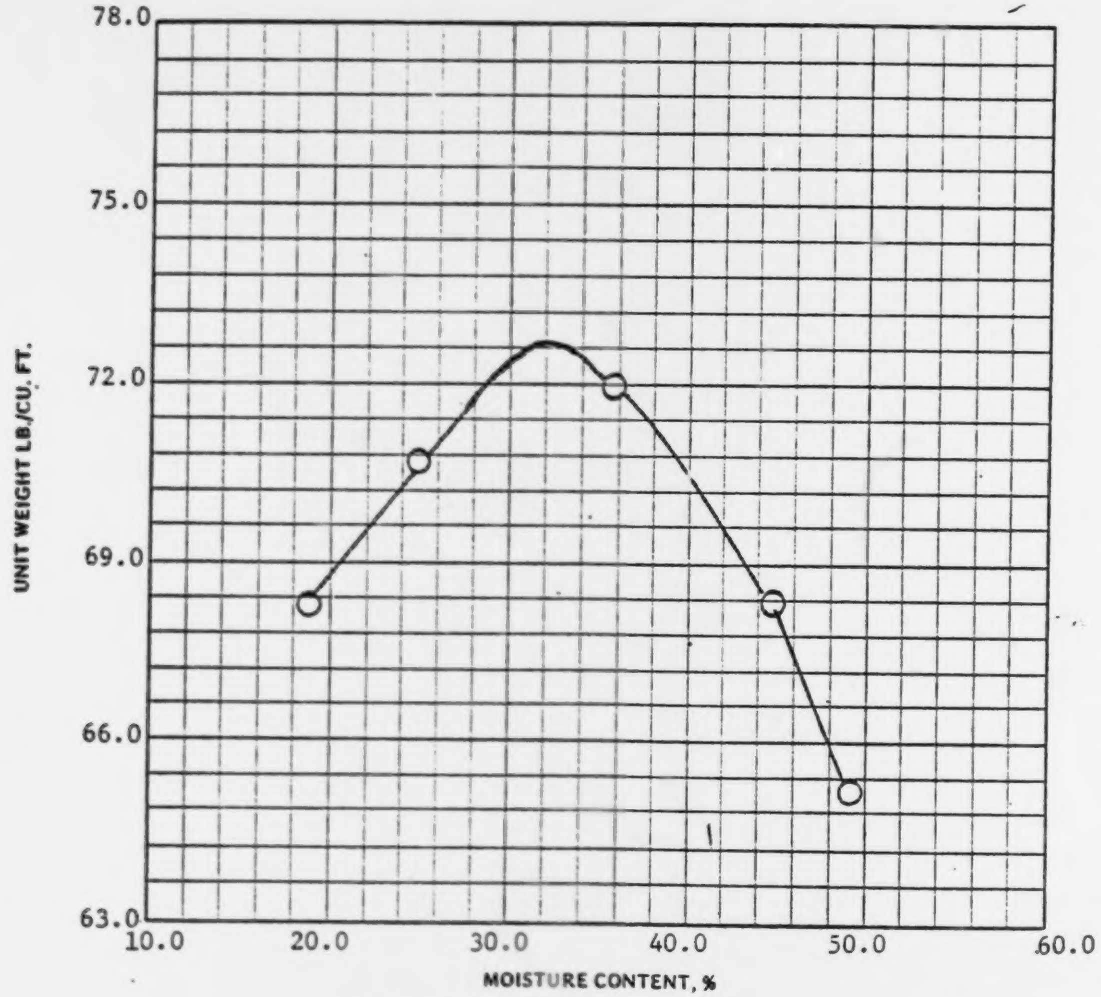
Water Content: 33.9%

BOWSER-MORNER Testing Laboratories, Inc.
CORPORATE ADDRESS • 420 Davis Ave. • P.O. Box 51 • Dayton, Ohio 45401 • 513/253-8805
TOLEDO DISTRICT • 122 S. St. Clair St. • P.O. Box 838 • Toledo, Ohio 43696 • 419/255-8200
KENTUCKY DISTRICT • Route 8 West • P.O. Box 636 • Maysville, Kentucky 41056 • 606/564-5508

REPORT OF PROCTOR CURVE

Arthur D. Little

PROJECT: New Elrama Disposal Site, Pennsylvania
MATERIAL: Gray Poz-E-Tec (New)
SOURCE OF MATERIAL: Jobsite



Type Proctor ASTM D698-70 Method C (Replaced) Standard

Maximum Dry Density 72.7 Lbs./cu. ft. Optimum Moisture Content 32.1* %

*140°F

2A11b

Compression Test of Poz-E-Tec Core

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Material Description:	Gray Poz-E-Tex Block #9 (Old)
Curing Period:	None

SPECIMEN DATA

Dimensions in inches,

Height as capped:	5.414
Diameter:	2.724
Length/Diameter Ratio:	1.98
Corrected PSI:	270

COMPRESSION TEST OF POZ-E-TEC CORES

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Material Description:	Gray Poz-E-Tec, point #8, new
Method of Compaction:	Dynamic
Curing Period:	24 hours

SPECIMEN DATA

Dimensions in inches,	
Height as capped:	4.313
Diameter:	4.015
Unit Load, psi:	11
Initial Moisture Content (%):	51.7
Initial Wet Unit Weight (pcf)	98.4
Initial Dry Unit Weight (pcf)	64.9
% Compaction:	89.3

COMPRESSION TEST OF POZ-E-TEC CORES

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Material Description: Gray Poz-E-Tec, point #9, new

Method of Compaction: Dynamic

Curing Period: 28 days

SPECIMEN DATA

Dimensions in inches,
  Height as capped: 4.875
  Diameter: 4.165

Unit Load, psi: 220

Initial Moisture Content (%) 52.3

Initial Wet Unit Weight (pcf) 98.4

Initial Dry Unit Weight (pcf) 64.6

% Compaction: 88.2

COMPRESSION TEST OF POZ-E-TEC CORES

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Material Description:	Gray Poz-E-Tec, point #10, new
Method of Compaction:	Dynamic
Curing Period:	28 days

SPECIMEN DATA

Dimensions in inches,	
Height as capped:	4.996
Diameter:	4.037
Unit Load, psi:	200
Initial Moisture Content, %:	50.7
Initial Wet Unit Weight (pcf):	96.6
Initial Dry Unit Weight (pcf):	63.5
% Compaction:	88.2

Constant Head

Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.:	1-6
Sample No.:	1U
Depth Interval of Sample:	2.5' - 4.0'
Depth Interval of Test Specimen:	3.5' - 3.7'

SPECIMEN DATA:

Dimensions, inches,	
Height:	2.004
Diameter:	2.869
Weight, lbs.,	
Initial:	0.73
Moisture Content, %:	
Initial:	38.2
Final:	41.1
Wet Unit Weight, pcf,	
Initial:	97.4
Final:	99.5
Dry Unit Weight, pcf,	
Initial:	70.5
Back Pressure Saturation, psi,	
Pressures:	10.0
Material Description:	Gray Poz-e-tec
Permeability, cm/sec,	
k:	5×10^{-6}

Constant Head

Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.: 1-6

Sample No.: 1U

Depth Interval of Sample: 2.5' - 4.0'

Depth Interval of Test Specimen: 3.8' - 4.0'

Curing Pencil: 28 days in 73°F and 100% humidity room

SPECIMEN DATA:

Dimensions, inches,

- Height: 1.423
- Diameter: 2.884

Weight, lbs.,

- Initial: 0.50

Moisture Content, %:

- Initial: 42.6
- Final: 57.0

Wet Unit Weight, pcf,

- Initial: 92.9
- Final: 102.3

Dry Unit Weight, pcf,

- Initial: 65.1

Back Pressure Saturation, psi,

- Pressures: 10.0, 20.0

Material Description: Gray Poz-e-tec

Permeability, cm/sec,

- k: 7×10^{-6}

Constant Head

Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.:	1-6
Sample No.:	2U
Depth Interval of Sample:	8.0' - 10.0'
Depth Interval of Test Specimen:	9.4' - 9.6'

SPECIMEN DATA:

Dimensions, inches,	
Height:	2.195
Diameter:	2.829
Weight, lbs.,	
Initial:	0.62
Moisture Content, %:	
Initial:	29.0
Final:	52.0
Wet Unit Weight, pcf,	
Initial:	77.7
Final:	91.5
Dry Unit Weight, pcf,	
Initial:	60.2
Back Pressure Saturation, psi,	
Pressures:	10.0
Material Description:	Gray Poz-e-tec
Permeability, cm/sec,	
k:	2×10^{-4}

Constant Head

Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.: 1-6

Sample No.: 4U

Depth Interval of Sample: 20.0' - 22.0'

Depth Interval of Test Specimen: 21.4' - 21.6'

SPECIMEN DATA:

Dimensions, inches,

- Height: 2.009
- Diameter: 2.791

Weight, lbs.,

- Initial: 0.72

Moisture Content, %:

- Initial: 40.8
- Final: 43.6

Wet Unit Weight, pcf,

- Initial: 101.6
- Final: 103.7

Dry Unit Weight, pcf,

- Initial: 72.2

Back Pressure Saturation, psi,

- Pressures: 10.0

Material Description: Gray Fly Ash

Permeability, cm/sec,

- k: 1×10^{-6}

Constant Head

Permeability Test

Project:	Arthur D. Little, New Elrama Disposal Site, Pennsylvania
Boring No.:	1-6
Sample No.:	8U
Depth Interval of Sample:	64.0' - 66.0'
Depth Interval of Test Specimen:	65.9' - 66.0'

SPECIMEN DATA:

Dimensions, inches,	
Height:	2.029
Diameter:	2.736
Weight, lbs.,	
Initial:	0.71
Moisture Content, %:	
Initial:	59.4
Final:	61.9
Wet Unit Weight, pcf,	
Initial:	102.9
Final:	104.6
Dry Unit Weight, pcf,	
Initial:	64.6
Back Pressure Saturation, psi,	
Pressures:	10.0
Material Description:	Gray Poz-e-tec
Permeability, cm/sec,	
k:	6×10^{-6}

Constant Head

Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.: 1-15

Sample No.: 1U

Depth Interval of Sample: 13.0' - 15.0'

Depth Interval of Test Specimen: 13.3' - 13.8'

SPECIMEN DATA:

Dimensions, inches,

Height: 5.984

Diameter: 2.834

Weight, lbs.,

Initial: 1.62

Moisture Content, %:

Initial: 49.6

Final: 74.0

Wet Unit Weight, pcf,

Initial: 74.2

Final: 86.3

Dry Unit Weight, pcf,

Initial: 49.6

Back Pressure Saturation, psi,

Pressures: 5.0

Material Description: Gray Poz-e-tec

Permeability, cm/sec,

k: 1×10^{-5}

Constant Head

Permeability Test

Project:	Arthur D. Little, New Elrama Disposal Site, Pennsylvania
Boring No.:	1-15
Sample No.:	2U
Depth Interval of Sample:	17.0' - 18.5'
Depth Interval of Test Specimen:	18.2' - 18.3'

SPECIMEN DATA:

Dimensions, inches,	
Height:	2.028
Diameter:	2.836
Weight, lbs.,	
Initial:	0.71
Moisture Content, %:	
Initial:	49.4
Final:	61.2
Wet Unit Weight, pcf,	
Initial:	95.8
Final:	103.3
Dry Unit Weight, pcf,	
Initial:	64.1
Back Pressure Saturation, psi,	
Pressures:	10.0
Material Description:	Black Fly Ash
Permeability, cm/sec,	
k:	2×10^{-5}

Constant Head

Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.:	1-15
Sample No.:	4U
Depth Interval of Sample:	37.0' - 39.0'
Depth Interval of Test Specimen:	38.3' - 38.4'

SPECIMEN DATA:

Dimensions, inches,	
Height:	2.044
Diameter:	2.795
Weight, lbs.,	
Initial:	0.85
Moisture Content, %:	
Initial:	26.8
Final:	27.7
Wet Unit Weight, pcf,	
Initial:	117.1
Final:	118.0
Dry Unit Weight, pcf,	
Initial:	92.4
Back Pressure Saturation, psi,	
Pressures:	10.0
Material Description:	Gray Fly Ash
Permeability, cm/sec,	
k:	6×10^{-6}

Constant Head

Permeability Test

Project:	Arthur D. Little, New Elrama Disposal Site, Pennsylvania
Boring No.:	1-15A
Sample No.:	3U
Depth Interval of Sample:	13.0' - 15.0'
Depth Interval of Test Specimen:	14.7' - 14.8'
SPECIMEN DATA:	
Dimensions, inches,	
Height:	2.040
Diameter:	2.768
Weight, lbs.,	
Initial:	0.63
Moisture Content, %:	
Initial:	62.6
Final:	68.8
Wet Unit Weight, pcf,	
Initial:	88.3
Final:	91.7
Dry Unit Weight, pcf,	
Initial:	54.3
Back Pressure Saturation, psi,	
Pressures:	10.0
Material Description:	Gray Fly Ash
Permeability, cm/sec,	
k:	7×10^{-6}

CONSTANT HEAD PERMEABILITY
Laboratory Compacted

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Material Description: Gray Poz-e-tec, Point #2, new

Method of Compaction: Dynamic

Curing Period: 28 days

SPECIMEN DATA

Compaction Data:
  Maximum Dry Unit Weight: 72.7 pcf
  Optimum Moisture Content: 32.1%
  Test Method: ASTM D698-70 - Method "C" (Replaced) Standard

Dimensions:
  Height: 4.613"
  Diameter: 3.922"

Weight, lbs.:
  Initial: 3.21

Moisture Content, %:
  Initial: 37.5
  Final: 43.1

Wet Unit Weight, pcf:
  Initial: 99.5
  Final: 103.6

Dry Unit Weight, pcf:
  Initial: 72.4
% Compaction: 99.6

Back Pressure Saturation, psi:
  Pressures: 10.0, 20.0

Permeability, cm/sec:
  k: 2×10^{-6}

CONSTANT HEAD PERMEABILITY

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Material Description: Gray Poz-e-tec, Point #3, new

Method of Compaction: Dynamic

Curing Period: 28 days

SPECIMEN DATA

Compaction Data:
  Maximum Dry Unit Weight: 72.7 pcf
  Optimum Moisture Content: 32.1%
  Test Method: ASTM D698-70 - Method "C" (Replaced) Standard

Dimensions:
  Height: 4.652"
  Diameter: 3.932"

Weight, lbs.:
  Initial: 3.31

Moisture Content, %:
  Initial: 20.2
  Final: 29.8

Wet Unit Weight, pcf:
  Initial: 100.8
  Final: 108.9

Dry Unit Weight, pcf:
  Initial: 83.9
% Compaction: 115.4

Back Pressure Saturation, psi:
  Pressures: 10.0, 20.0

Permeability, cm/sec:
  k: 2×10^{-6}

CONSTANT HEAD PERMEABILITY
Laboratory Compacted

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania	
Material Description:	Gray Poz-e-tec, Point #4 new
Method of Compaction:	Dynamic
Curing Period:	28 days

SPECIMEN DATA

Compaction Data:	
Maximum Dry Unit Weight:	72.7 pcf
Optimum Moisture Content:	32.1%
Test Method: ASTM D698-70 - Method "C" (Replaced) Standard	
Dimensions:	
Height:	4.381
Diameter:	4.113
Weight, lbs.:	
Initial:	3.28
Moisture Content, %:	
Initial:	40.1
Final:	36.2
Wet Unit Weight, pcf:	
Initial:	97.4
Final:	94.7
Dry Unit Weight, pcf:	
Initial:	69.5
% Compaction:	95.6
Back Pressure Saturation, psi:	
Pressures:	10.0
Permeability, cm/sec:	
k:	3×10^{-6}

CONSTANT HEAD PERMEABILITY
Laboratory Compacted

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Material Description:	Gray Poz-e-tec, Point 6 new
Method of Compaction:	Dynamic
Curing Period:	33 days

SPECIMEN DATA

Compaction Data:	
Maximum Dry Unit Weight:	72.7 pcf
Optimum Moisture Content:	32.1%

Test Method: ASTM D1557-70 - Method "C" (Replaced) Standard

Dimensions:	
Height:	4.449
Diameter:	3.962
Weight, lbs.:	
Initial:	3.37
Moisture Content, %:	
Initial:	44.7
Final:	45.5
Wet Unit Weight, pcf:	
Initial:	106.2
Final:	106.8
Dry Unit Weight, pcf:	
Initial:	73.4
% Compaction:	101.0
Back Pressure Saturation, psi:	
Pressures:	10.0, 20.0
Permeability, cm/sec:	
k:	9 x 10^{-6}

Constant Head

Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Sample No.: Block #2

SPECIMEN DATA:

Dimensions, inches,

Height: 1.931

Diameter: 2.725

Weight, lbs.,

Initial: 0.61

Moisture Content, %:

Initial: 50.4

Final: 53.3

Wet Unit Weight, pcf,

Initial: 93.6

Final: 95.4

Dry Unit Weight, pcf,

Initial: 62.2

Back Pressure Saturation, psi,

Pressures: 10.0

Material Description: Old Poz-e-tec

Permeability, cm/sec,

k: 2×10^{-6}

Constant Head

Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Sample No.:	Block #4
SPECIMEN DATA:	
Dimensions, inches,	
Height:	1.958
Diameter:	2.705
Weight, lbs.,	
Initial:	0.60
Moisture Content, %:	
Initial:	51.1
Final:	55.1
Wet Unit Weight, pcf,	
Initial:	92.1
Final:	94.4
Dry Unit Weight, pcf,	
Initial:	60.9
Back Pressure Saturation, psi,	
Pressures:	10.0
Material Description:	Old Poz-e-tec
Permeability, cm/sec,	
k:	1×10^{-6}

Constant Head

Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Sample No.: Block #8

SPECIMEN DATA:

Dimensions, inches,

- Height: 2.014
- Diameter: 2.736

Weight, lbs.,

- Initial: 0.64

Moisture Content, %:

- Initial: 50.8
- Final: 54.8

Wet Unit Weight, pcf,

- Initial: 93.4
- Final: 95.8

Dry Unit Weight, pcf,

- Initial: 61.9

Back Pressure Saturation, psi,

- Pressures: 10.0

Material Description: Old Poz-e-tec

Permeability, cm/sec,

- k: 6 $\times 10^{-7}$

SPECIFIC GRAVITY

Project: Arthur D. Little, New Elrama Disposal Site, Pennyslvania

Boring No.:	1-6
Sample No.:	1U
Depth:	2.5' - 4.0'
Procedure:	ASTM-D854

TESTS RESULTS

Specific Gravity:	2.31
Material Description:	Gray Poz-e-tec

SPECIFIC GRAVITY

Project: Arthur D. Little, New Elrama Disposal Site, Pennyslvania

Boring No.:	1-6
Sample No.:	16S
Depth:	50.5' - 52.0'
Procedure:	ASTM-D854

TESTS RESULTS

Specific Gravity:	2.48
Material Description:	Gray Poz-e-tec

SPECIFIC GRAVITY

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.:	1-6
Sample No.:	8U
Depth:	64.0' - 66.0'
Procedure:	ASTM-854

TESTS RESULTS

Specific Gravity:	2.32
Material Description:	Gray Poz-e-tec

SPECIFIC GRAVITY

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.:	1-15A
Sample No.:	2U
Depth:	10.0' - 12.0'
Procedure:	ASTM-D854

TESTS RESULTS

Specific Gravity:	2.30
Material Description:	Gray Poz-e-tec

SPECIFIC GRAVITY

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.:	1-15
Sample No.:	1U
Depth:	13.0' - 15.0'
Procedure:	ASTM-D854

TESTS RESULTS

Specific Gravity:	2.38
Material Description:	Gray Poz-e-tec

SPECIFIC GRAVITY

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.:	1-15
Sample No.:	2U
Depth:	17.0' - 18.5'
Procedure:	ASTM-D854

TESTS RESULTS

Specific Gravity:	2.37
Material Description:	Gray Poz-e-tec

SPECIFIC GRAVITY

Project: Arthur D. Little, New Elrama Disposal Site, Pennysivania

Boring No.: 1-15

Sample No.: S7

Depth: 34.5' - 36.5'

Procedure: ASTM-D854

TESTS RESULTS

Specific Gravity: 2.30

Material Description: Gray Poz-e-tec

SPECIFIC GRAVITY

Project: Arthur D. Little, New Elrama Disposal Site, Pennyslvania

Boring No.:	---
Sample No.:	Block Sample
Depth:	---
Procedure:	ASTM-D854

TESTS RESULTS

Specific Gravity:	2.39
Material Description:	Gray Poz-e-tec (old)

Extended Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Sample No.: 5A

Material: Poz-e-tec

Age at Time of Test: 28 days

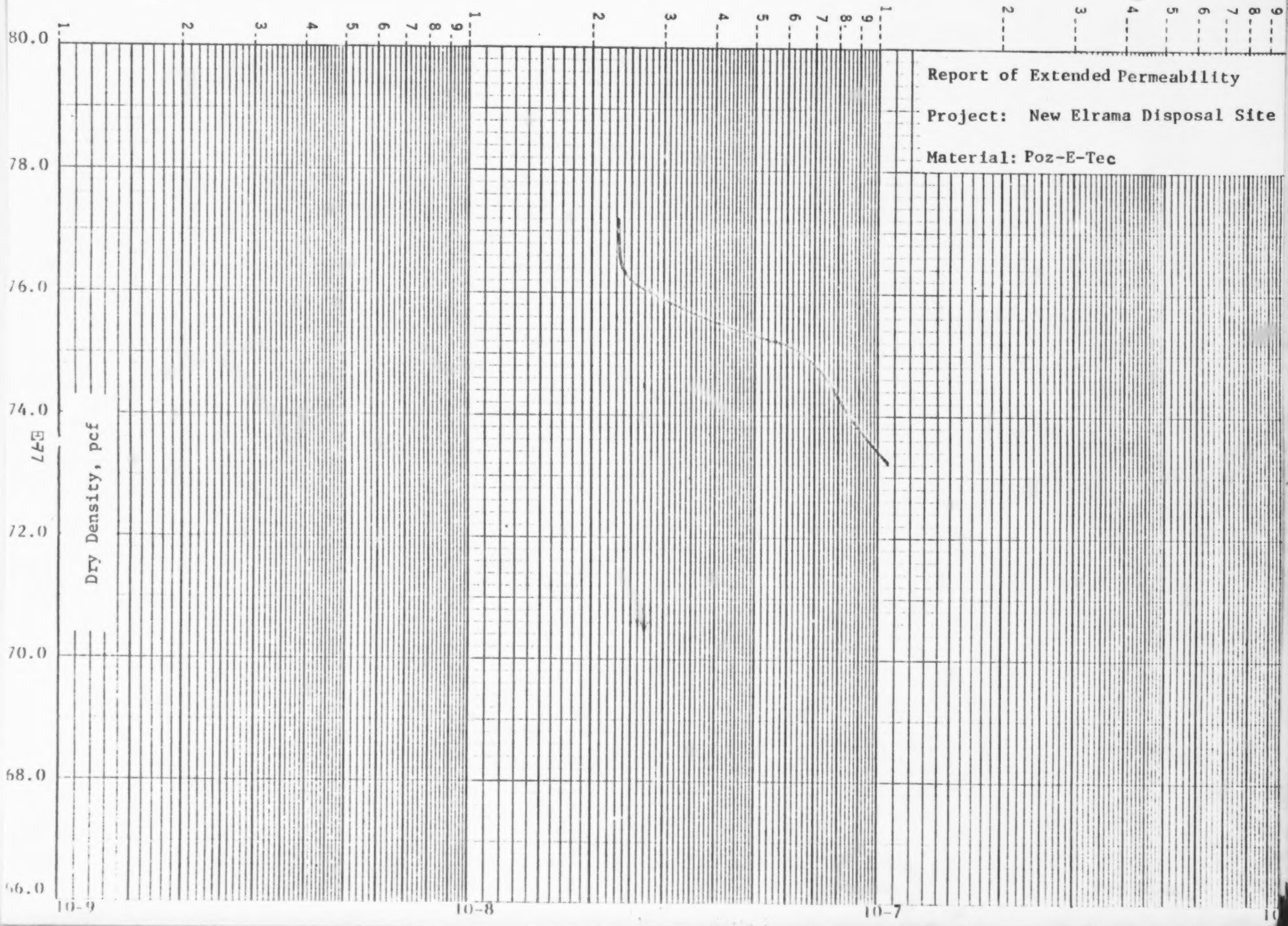
SPECIMEN DATA

Initial Conditions,

Height:	4.345"
Diameter:	4.030"
Weight:	3.28 lbs.
Moisture Content:	39.6%
Specific Gravity:	1.90
Wet Unit Weight:	102.1 pcf
Dry Unit Weight:	73.2 pcf

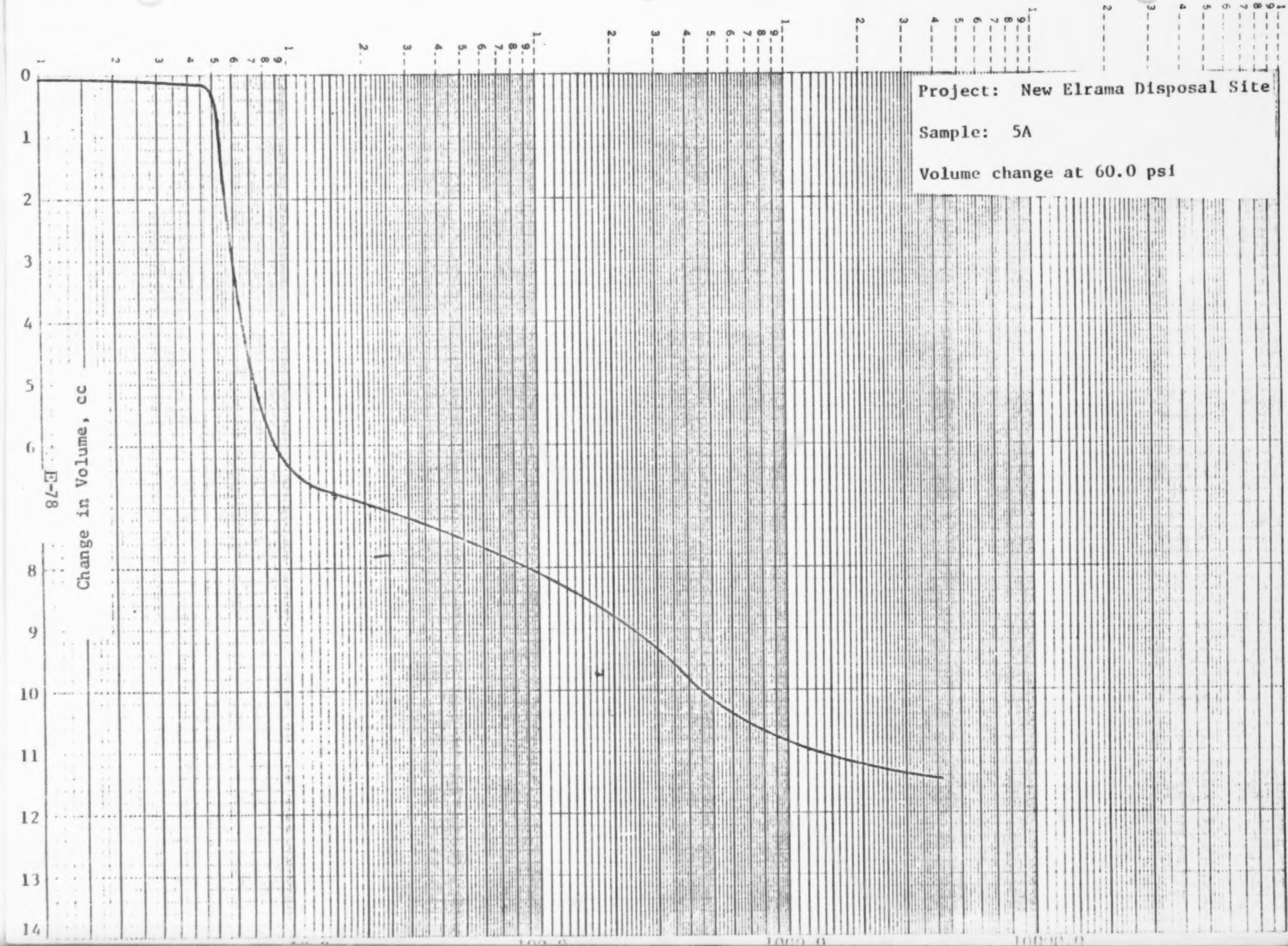
Test Summary
Graphical Presentation on Following Pages

Dry Unit Weight pcf	Permeability, k 10^{-7} cm/sec
73.2	16
74.1	8.3
74.9	4.0
75.5	3.0
76.2	2.4
77.2	2.4


Report of Extended Permeability

Project: New Elrama Disposal Site

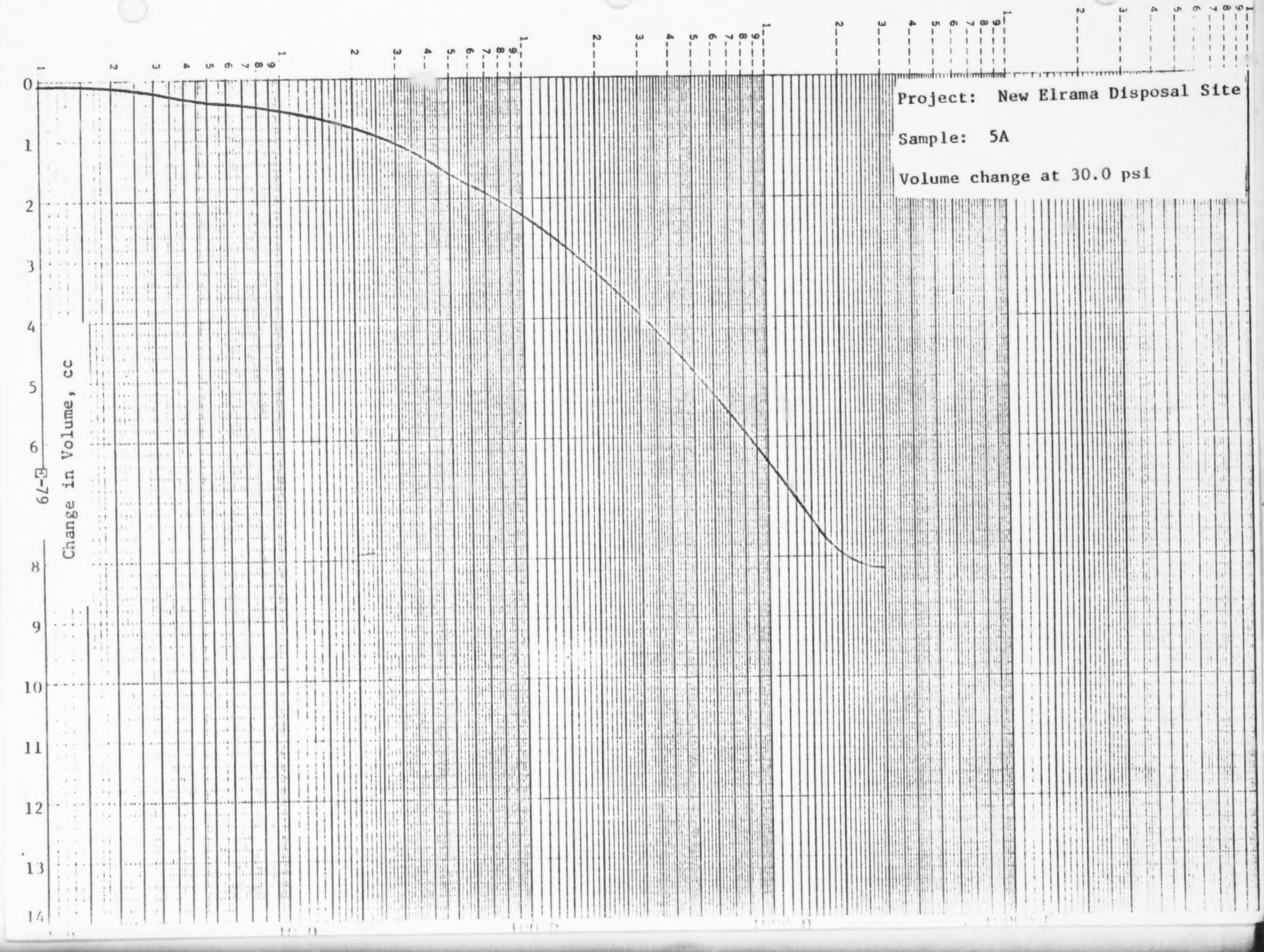
Material: Poz-E-Tec



Project: New Elrama Disposal Site

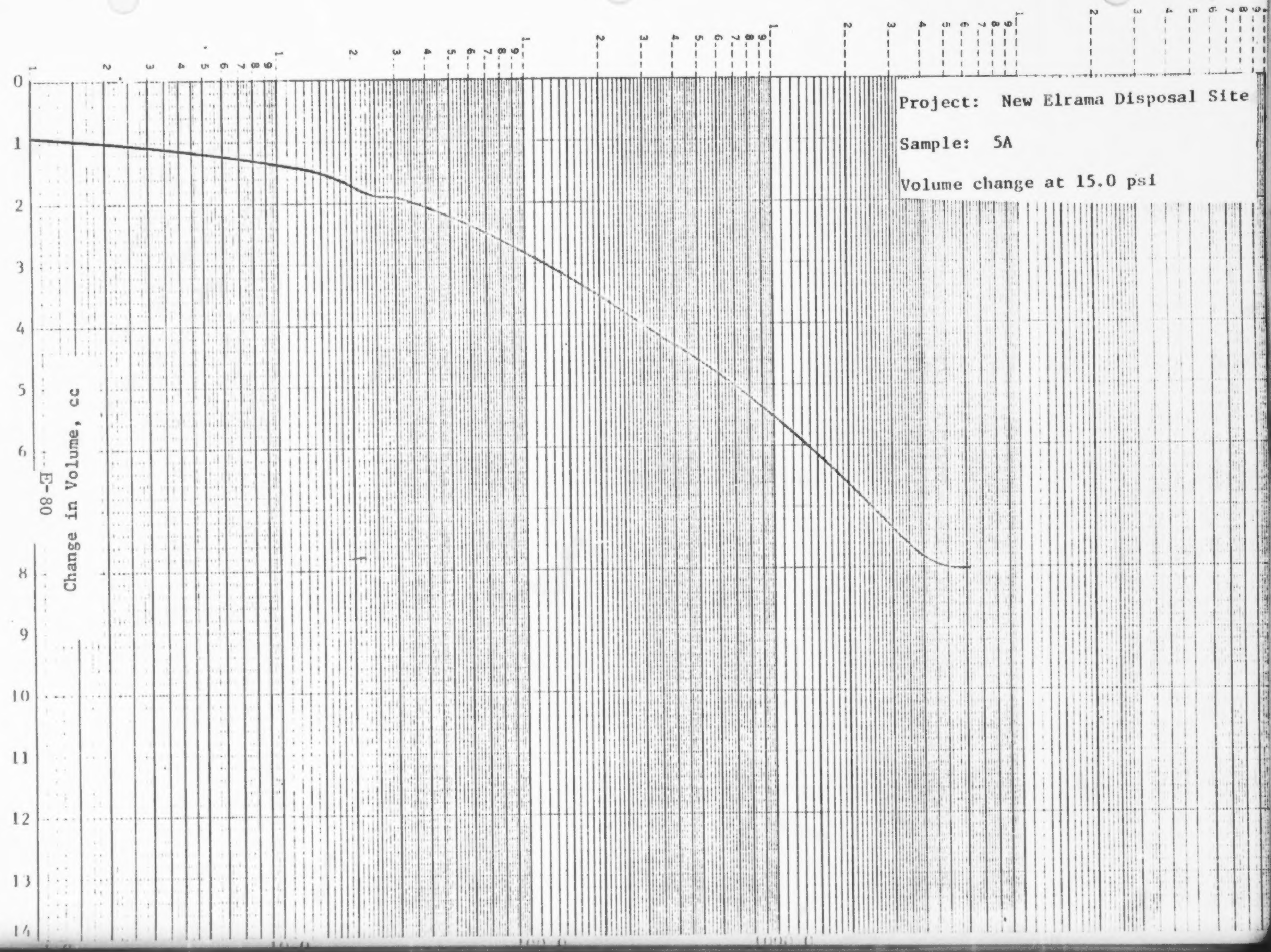
Sample: 5A

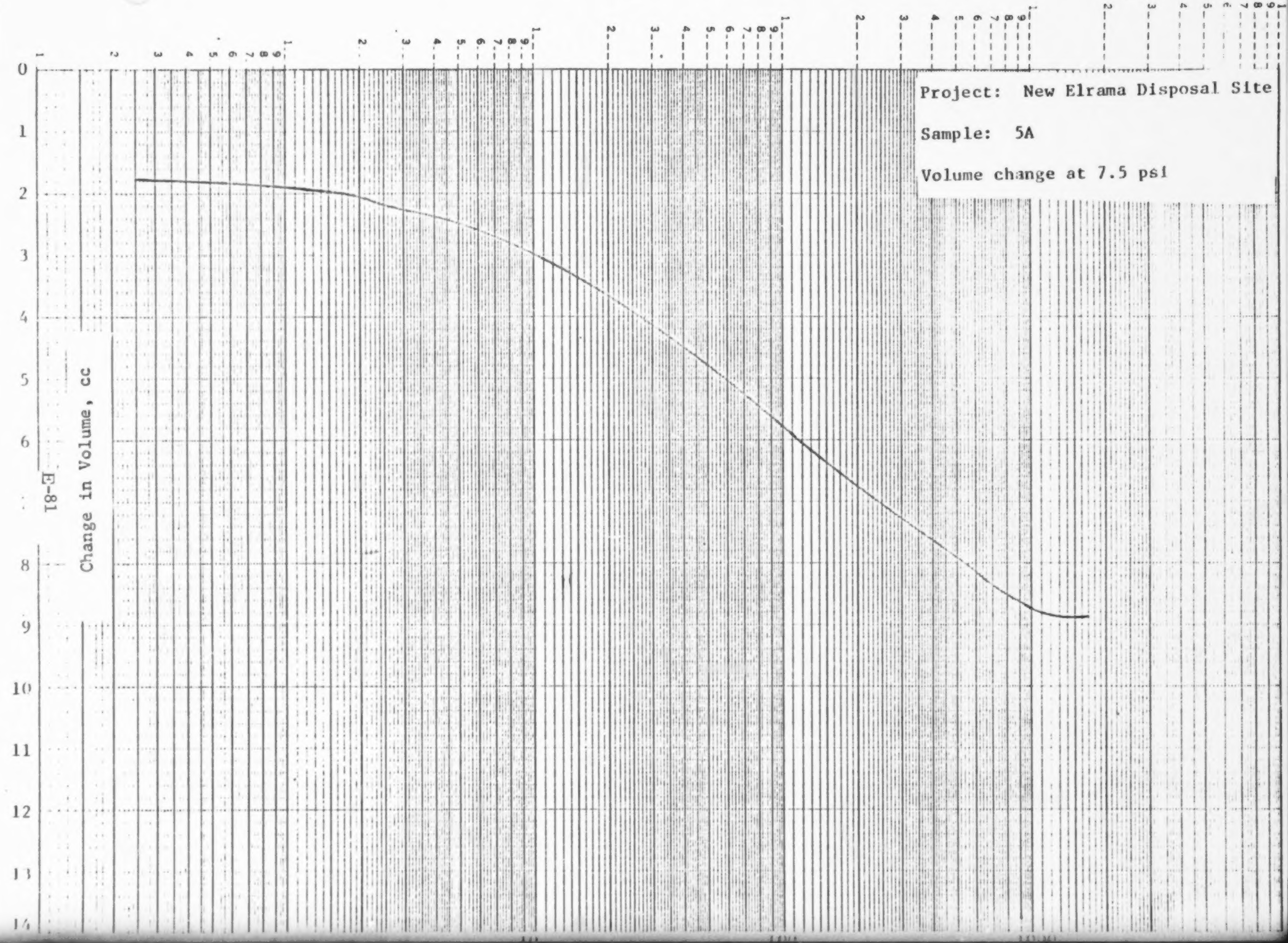
Volume change at 60.0 psi


Project: New Elrama Disposal Site

Sample: 5A

Volume change at 30.0 psi


Project: New Elrama Disposal Site
Sample: 5A
Volume change at 15.0 psi
Change in Volume, cc
0
1
2
3
4
5
6
8
9
10
11
12
13
14
1
2
3
4
5
6
7
8
9


Project: New Elrama Disposal Site
Sample: 5A
Volume change at 7.5 psi
Change in Volume, cc
0
1
2
3
4
5
6
8
9
10
11
12
13
14
1
2
3
4
5
6
7
8
9
1
2
3
4
5
6
7
8
9
1
2
3
4
5
6
7
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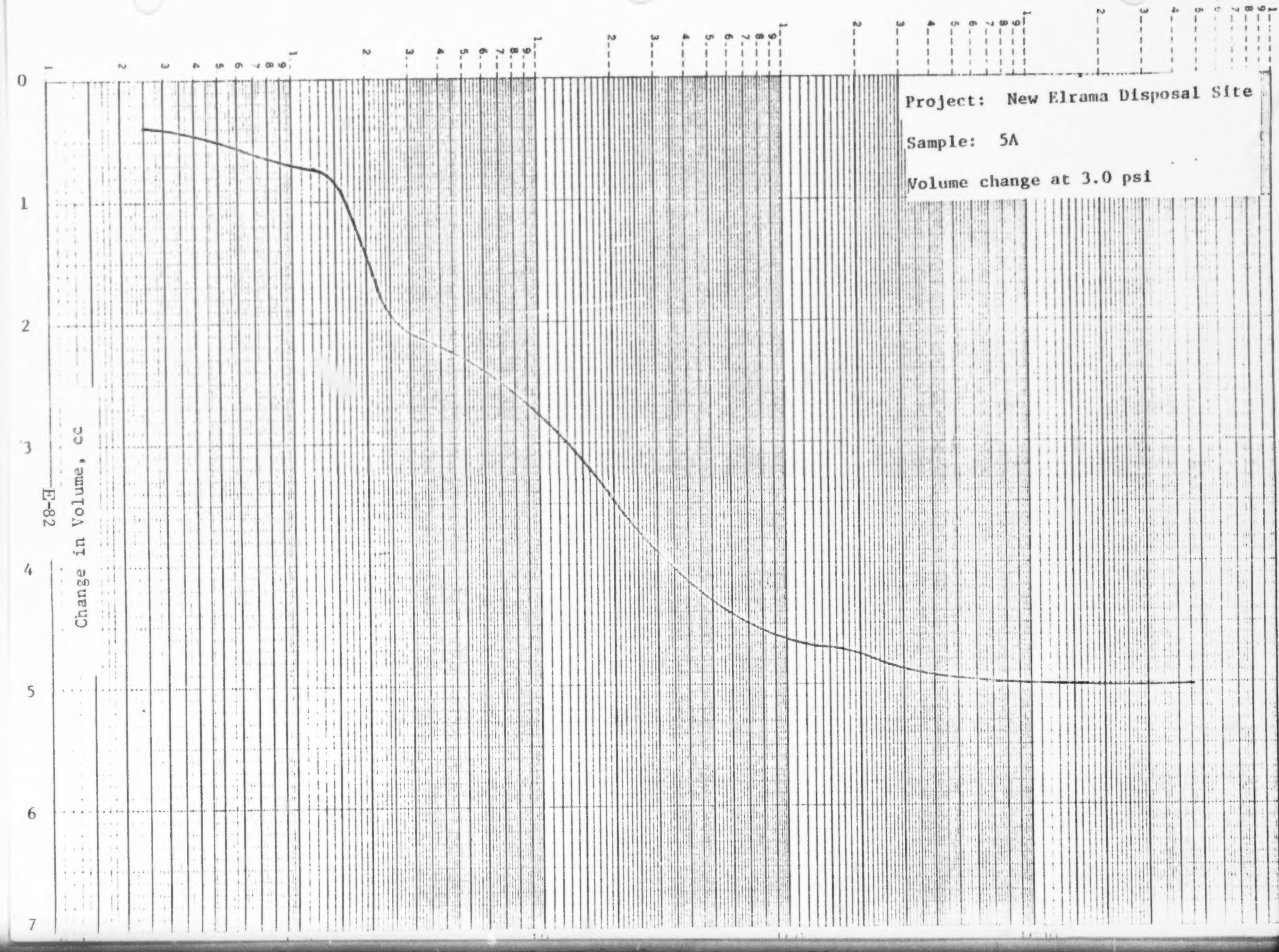
4
5
6
7
8
9
1



Project: New Elrama Disposal Site

Sample: 5A

Volume change at 3.0 psi

Extended Permeability Test

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.: 1-6

Sample No.: U-6

Depth Interval of Sample: 24.0' - 26.0'

Depth Interval of Test Specimen: 25.5' - 26.0'

SPECIMEN DATA

Initial Conditions,

Height:	5.923"
Diameter:	2.795"
Weight:	2.02 lbs.
Moisture Content:	55.3%
Specific Gravity:	2.44
Wet Unit Weight:	96.2 pcf
Dry Unit Weight:	61.9 pcf

Test Summary
Graphical Presentation on Following Pages

Dry Unit Weight pcf	Permeability, k 10^{-6} cm/sec
61.9	14
63.1	6.2
63.4	5.0
64.0	4.5
65.4	4.9

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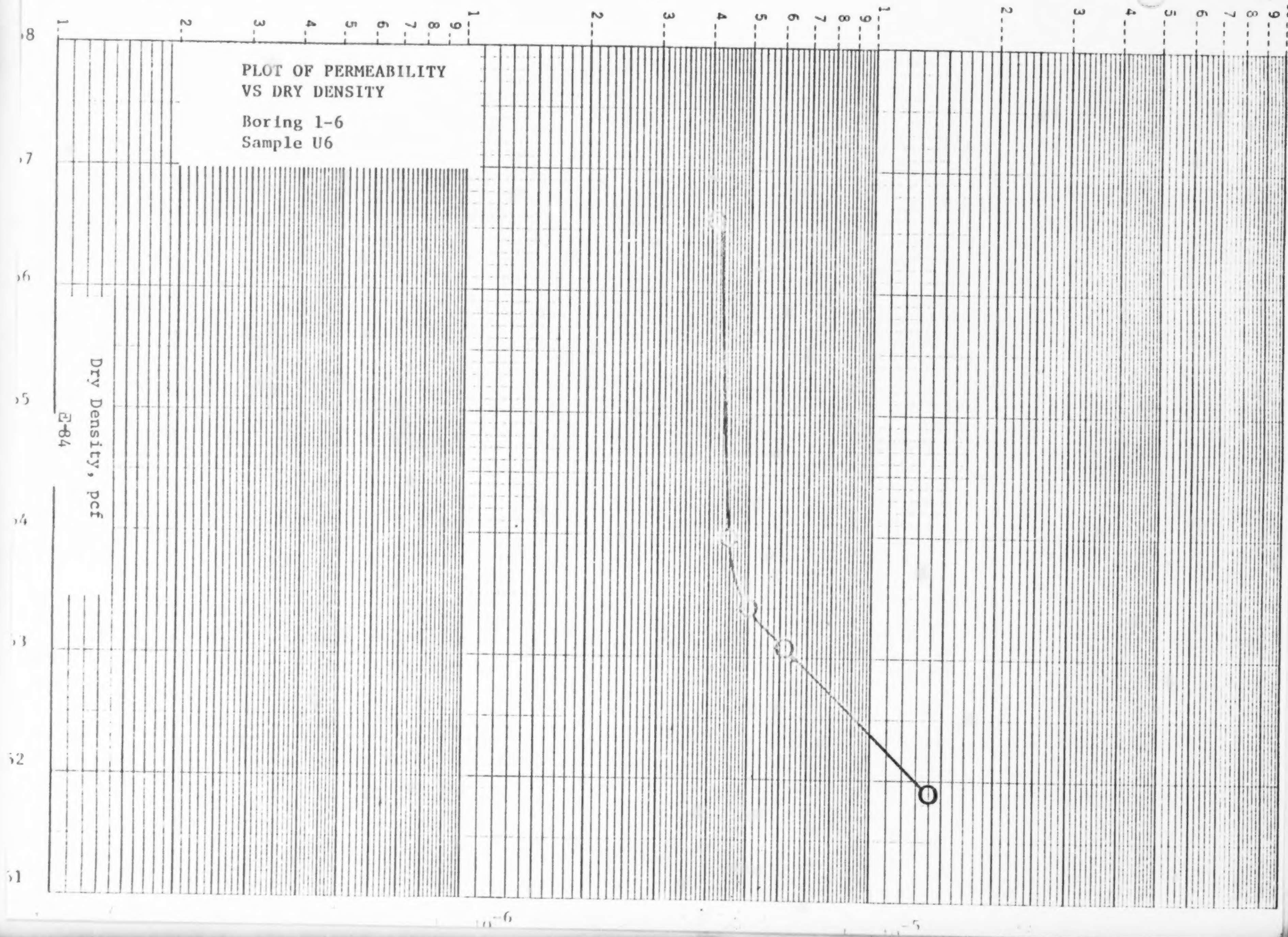
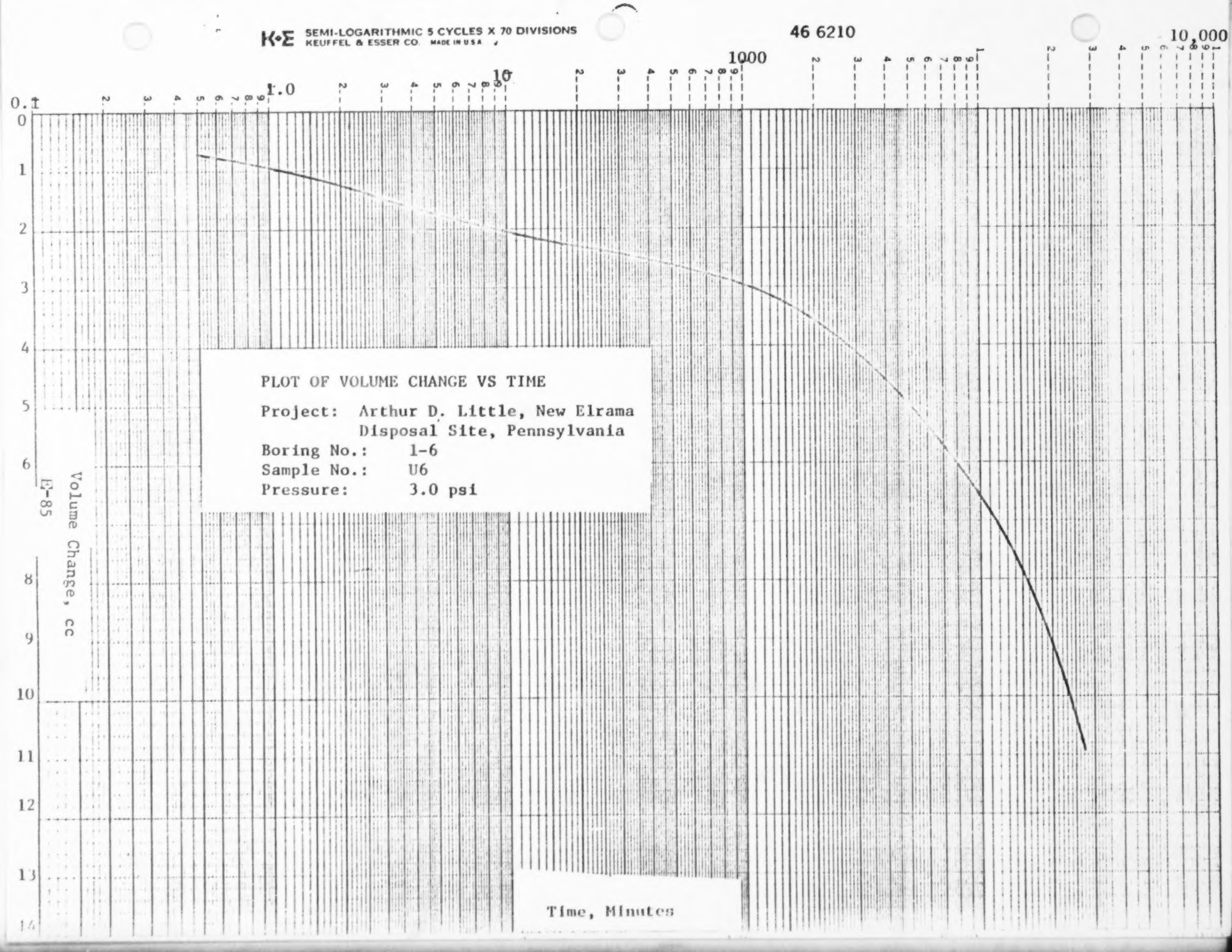


PLOT OF PERMEABILITY
VS DRY DENSITY

Boring 1-6
Sample U6

Dry Density, pcf



PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.: 1-6

Sample No.: U6

Pressure: 3.0 psi

K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
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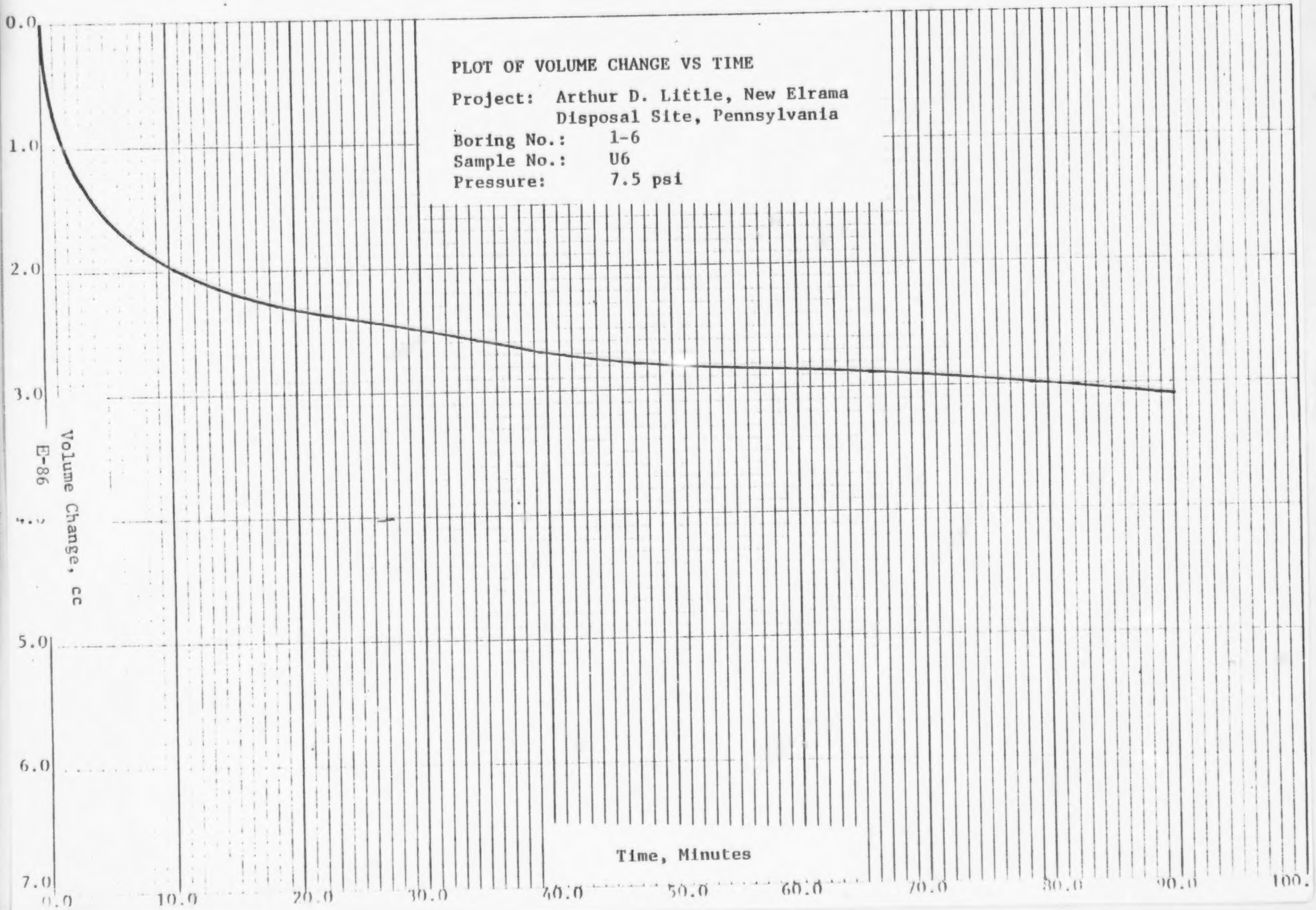
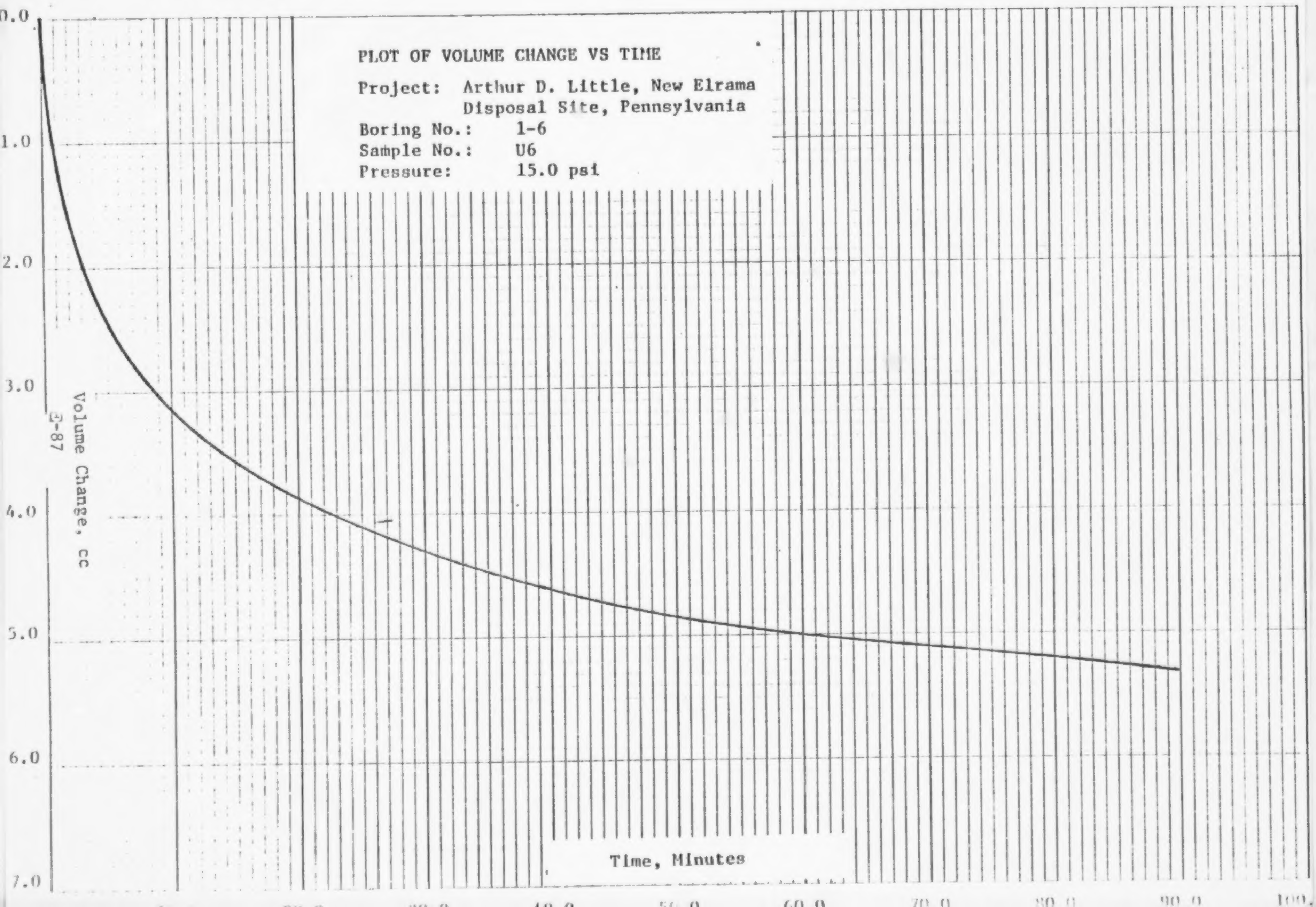
46 0700



PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little, New Elrama
Disposal Site, Pennsylvania
Boring No.: 1-6
Sample No.: U6
Pressure: 7.5 psi

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 0700



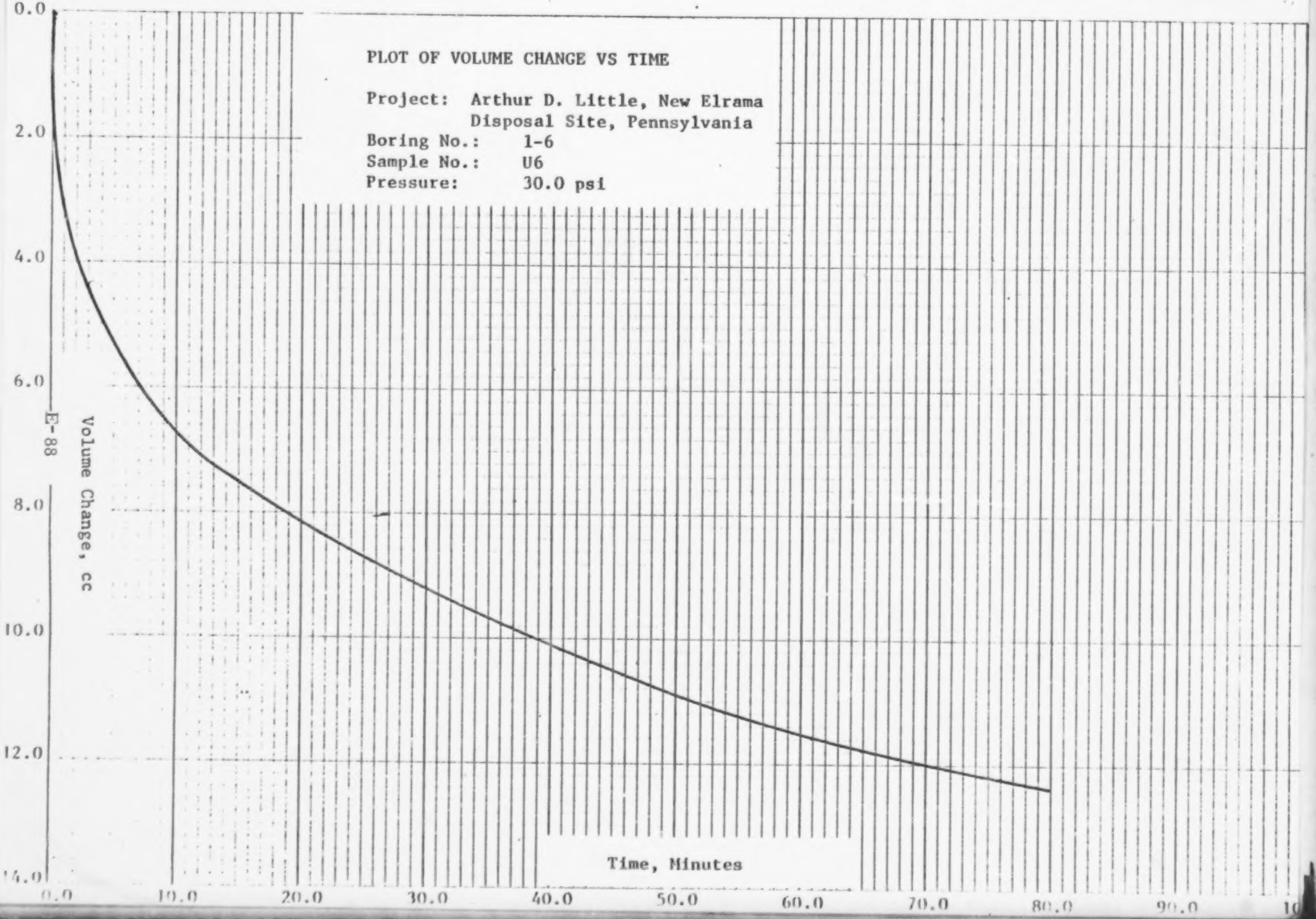
PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little, New Elrama
Disposal Site, Pennsylvania
Boring No.: 1-6
Sample No.: U6
Pressure: 15.0 psi

E-87

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0700

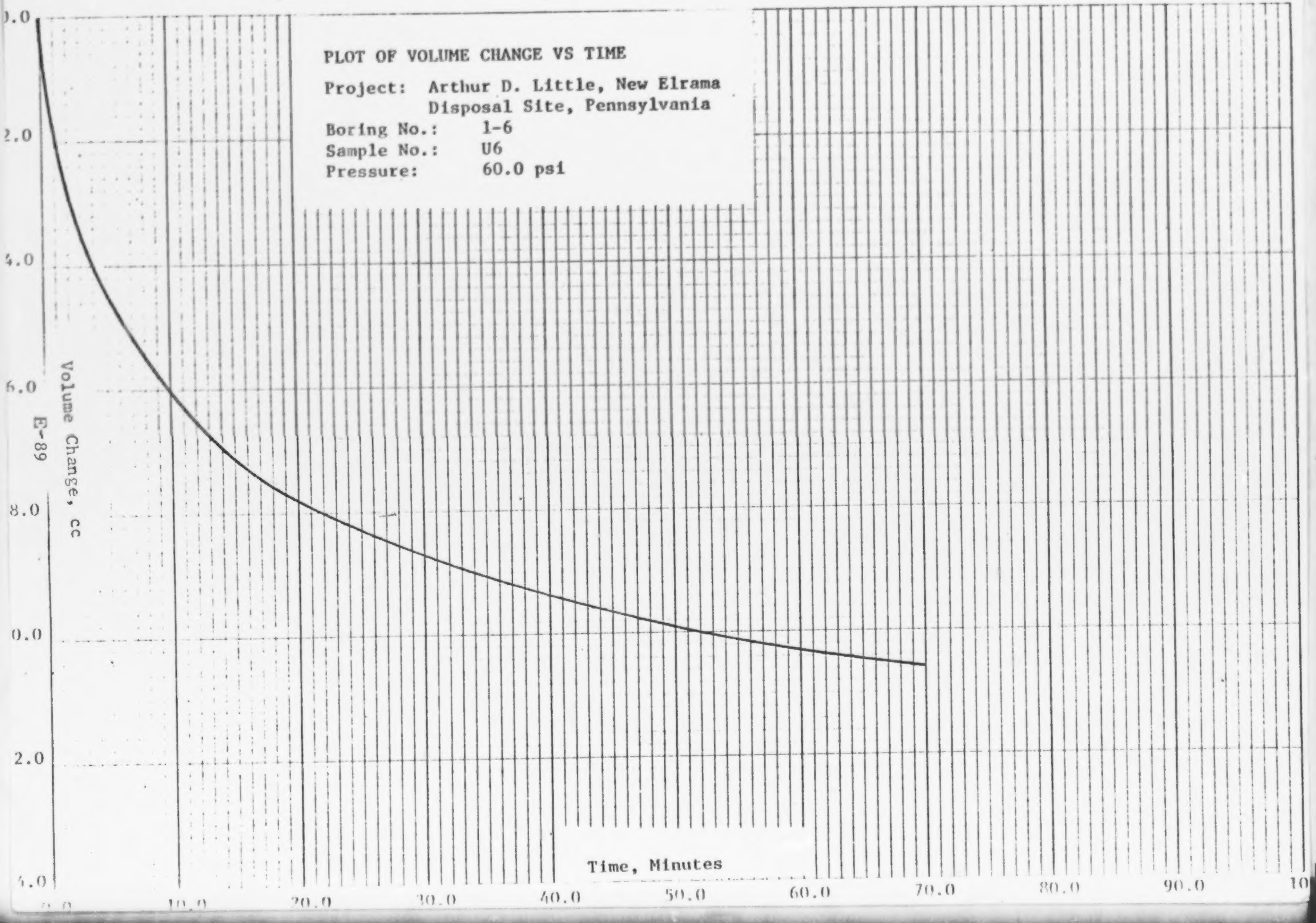


PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little, New Elrama
Disposal Site, Pennsylvania
Boring No.: 1-6
Sample No.: U6
Pressure: 30.0 psi

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

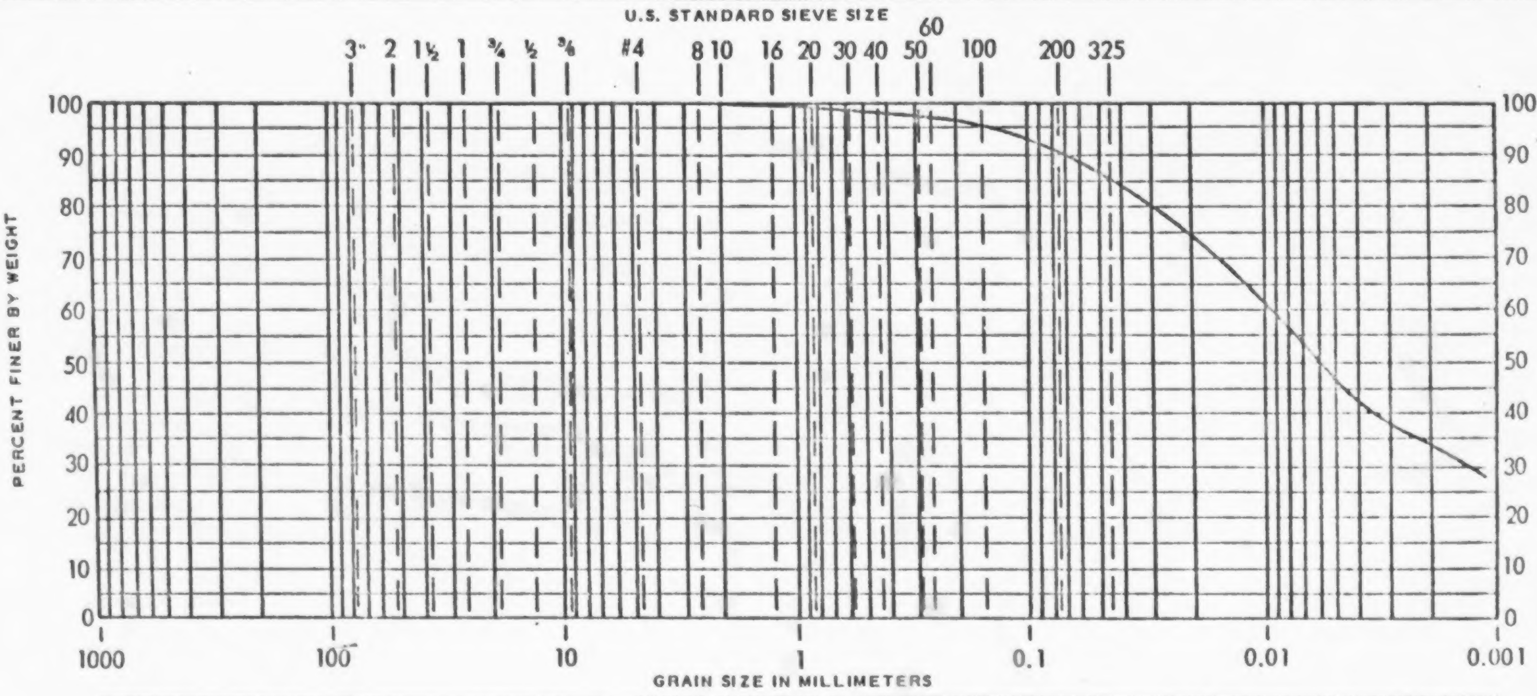
46 0700



PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little, New Elrama
Disposal Site, Pennsylvania
Boring No.: 1-6
Sample No.: U6
Pressure: 60.0 psi

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 0%		SAND 8%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	45%	47%

PROJECT	Arthur D. Little, New Elrama Disposal Site
BORING NO.	1-3
SAMPLE NO.	S-5
DEPTH	18.0-20.0'
CLASSIFICATION	"ML" "SILT"

NATURAL % MOISTURE	34.2
LIQUID LIMIT	48
PLASTIC LIMIT	40
PLASTICITY INDEX	8
COLOR	Lt. Brown
REMARKS	"U.S.C.S."

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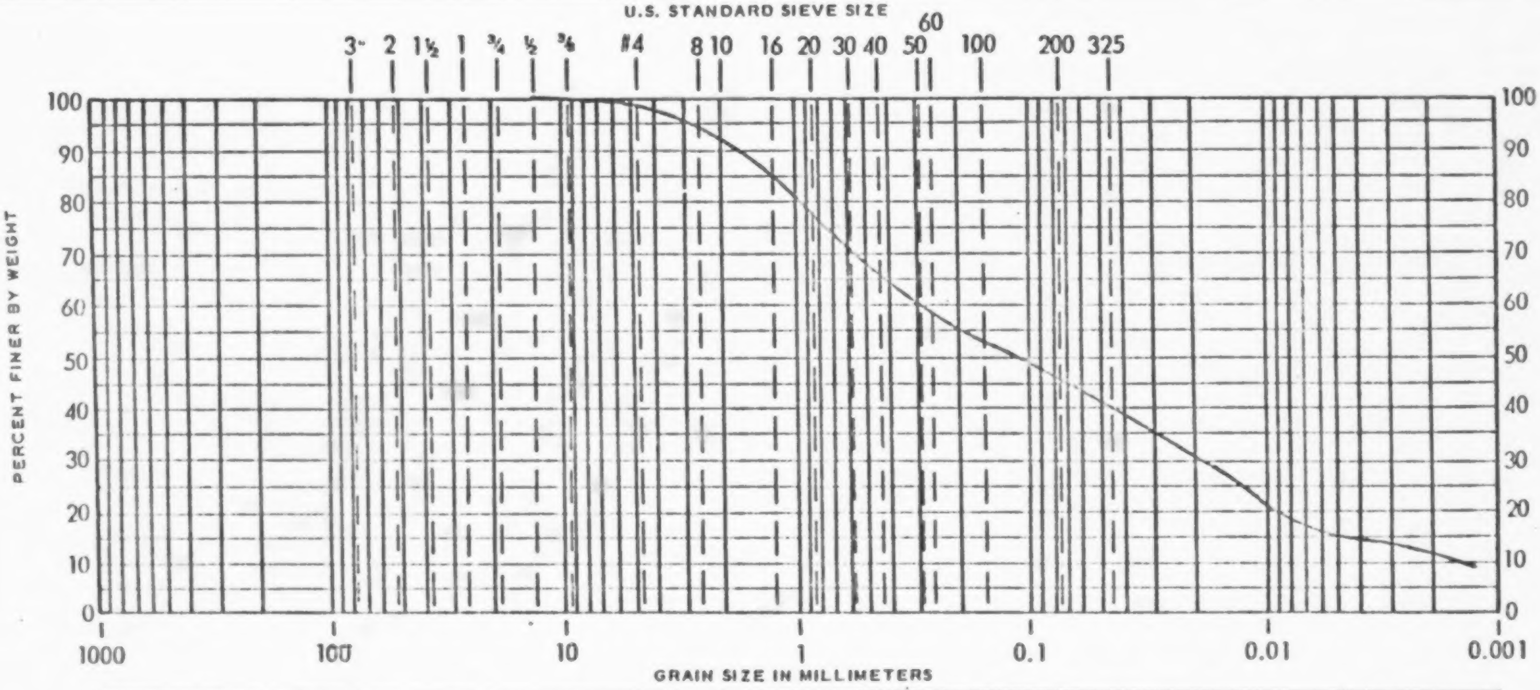

COBBLES	GRAVEL 2%		SAND 52%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	31%	15%

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-6
SAMPLE NO. 1U
DEPTH 2.5-4.0'
CLASSIFICATION "SM"
silty "SAND"

NATURAL % MOISTURE 38.2
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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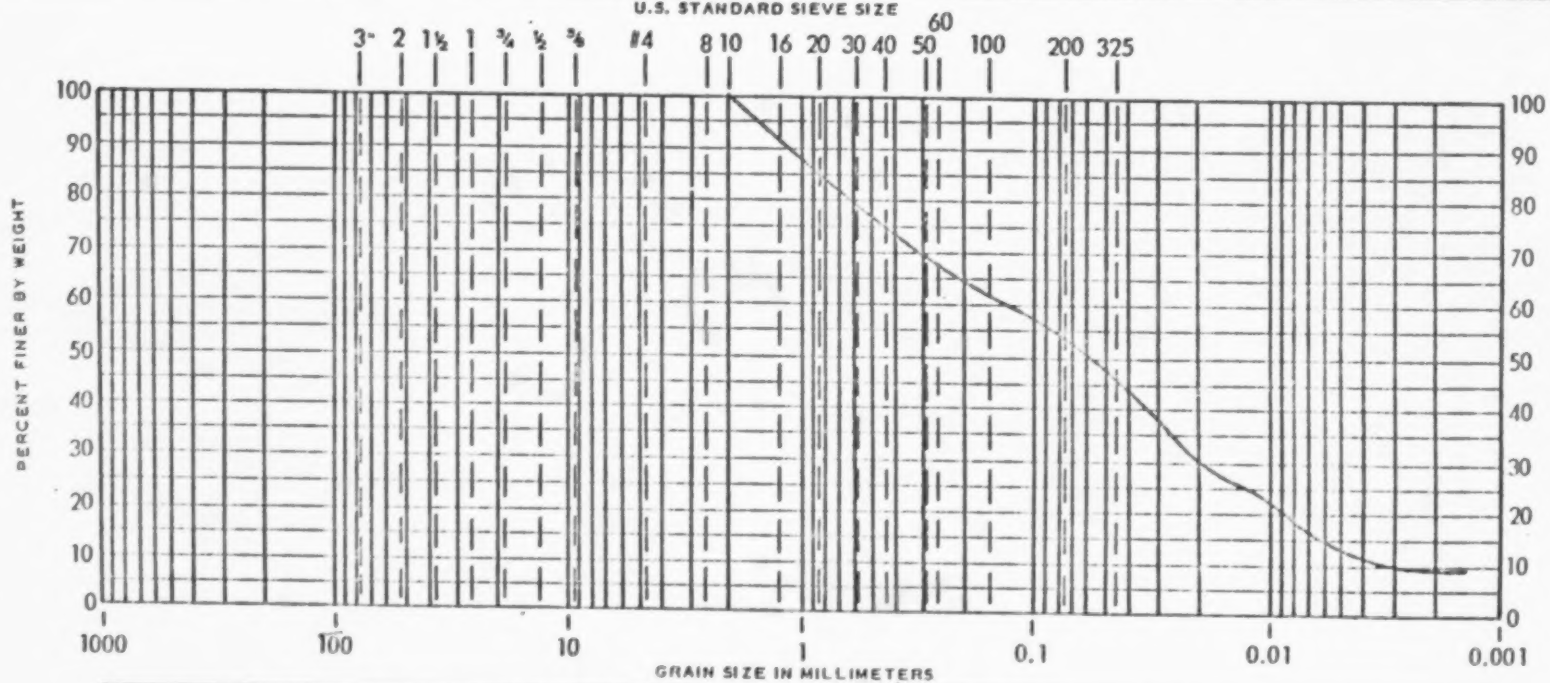

COBBLES	GRAVEL 0%		SAND 47%			SILT 38%	CLAY 15%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-6
SAMPLE NO. 4U
DEPTH 20.0-22.0'
CLASSIFICATION "ML"

silty "FINE SAND"

NATURAL % MOISTURE 34.7
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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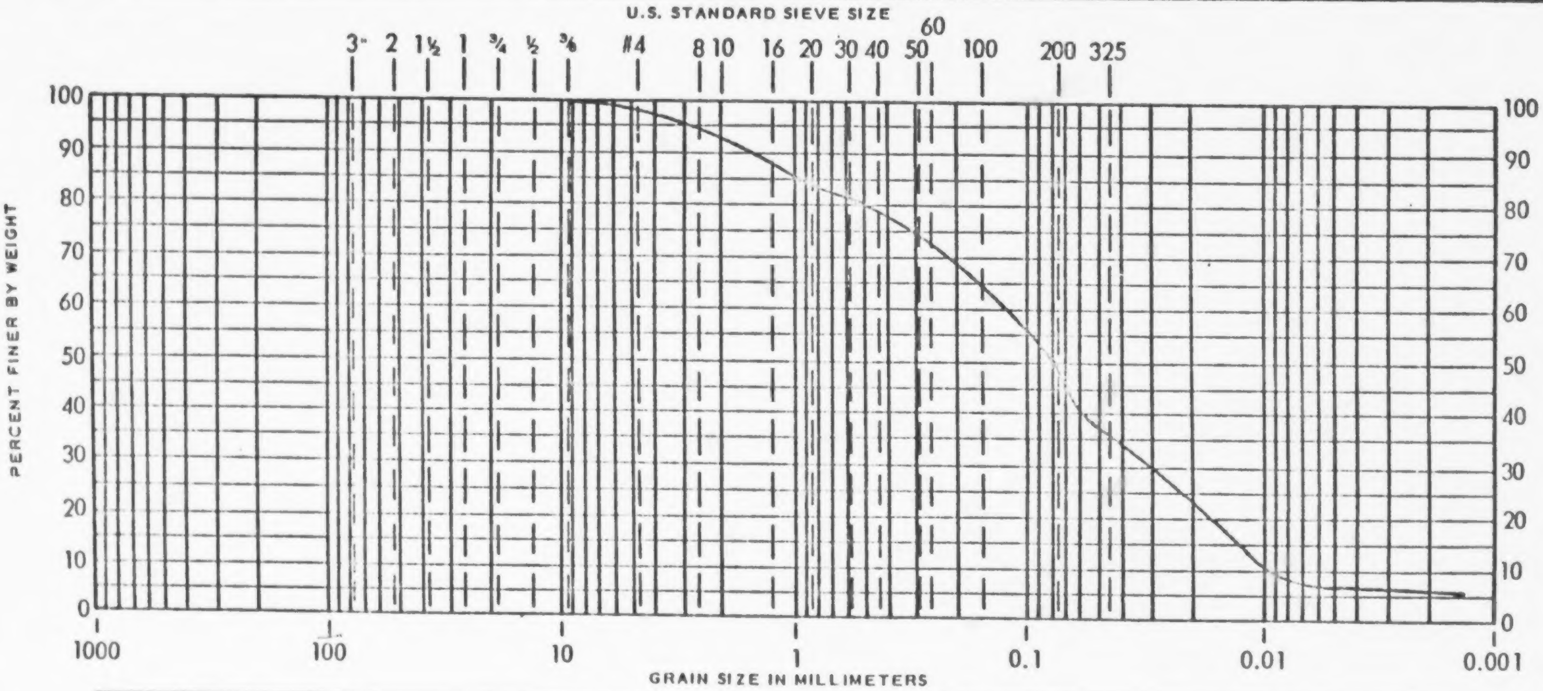
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 49%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	43%	7%

PROJECT Arthur D. Little, New
Elrama Disposal Site
BORING NO. 1-6
SAMPLE NO. U-6
DEPTH 34.5-36.0'
CLASSIFICATION "ML"

silty "FINE SAND"

NATURAL % MOISTURE 20.7
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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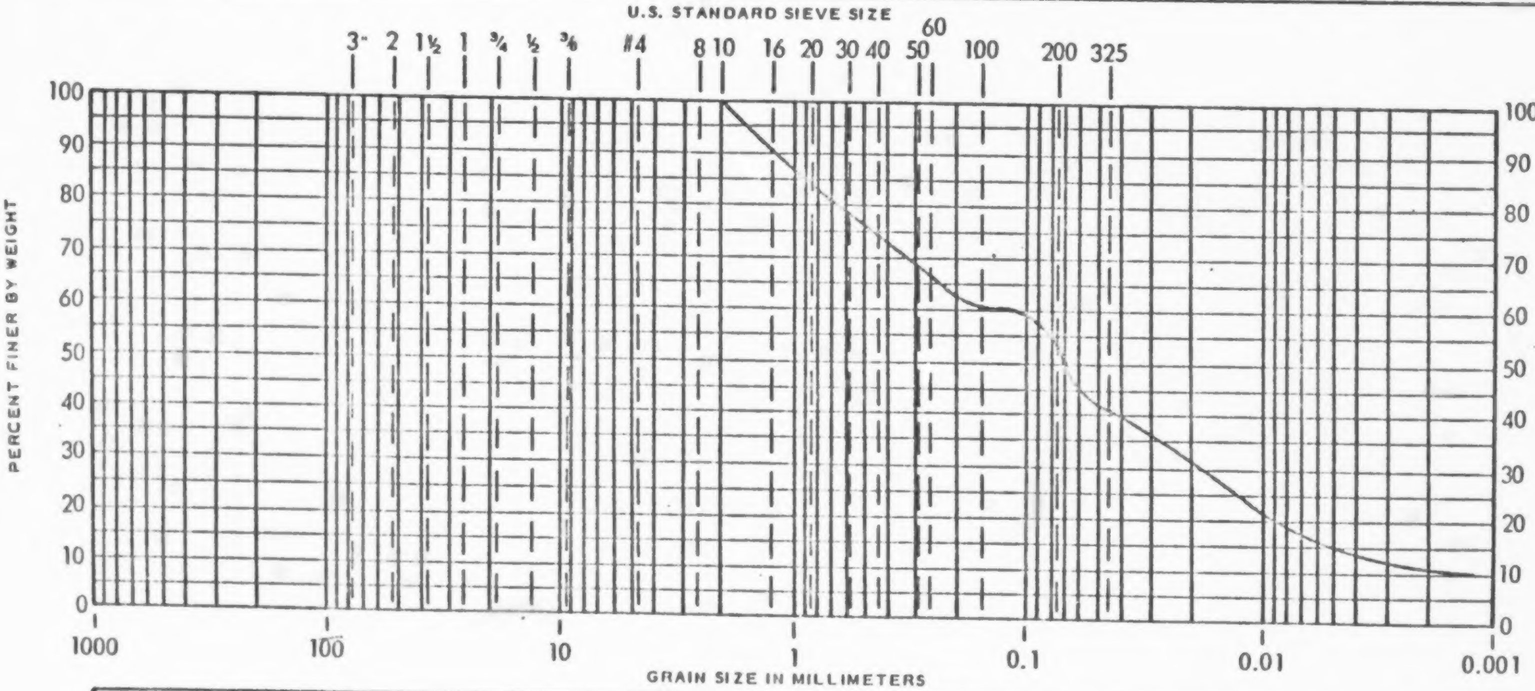

COBBLES	GRAVEL 0%		SAND 45%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	40%	15%

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-6
SAMPLE NO. 16S
DEPTH 50.5-52.0'
CLASSIFICATION "ML"

silty "FINE SAND"

NATURAL % MOISTURE 49.6
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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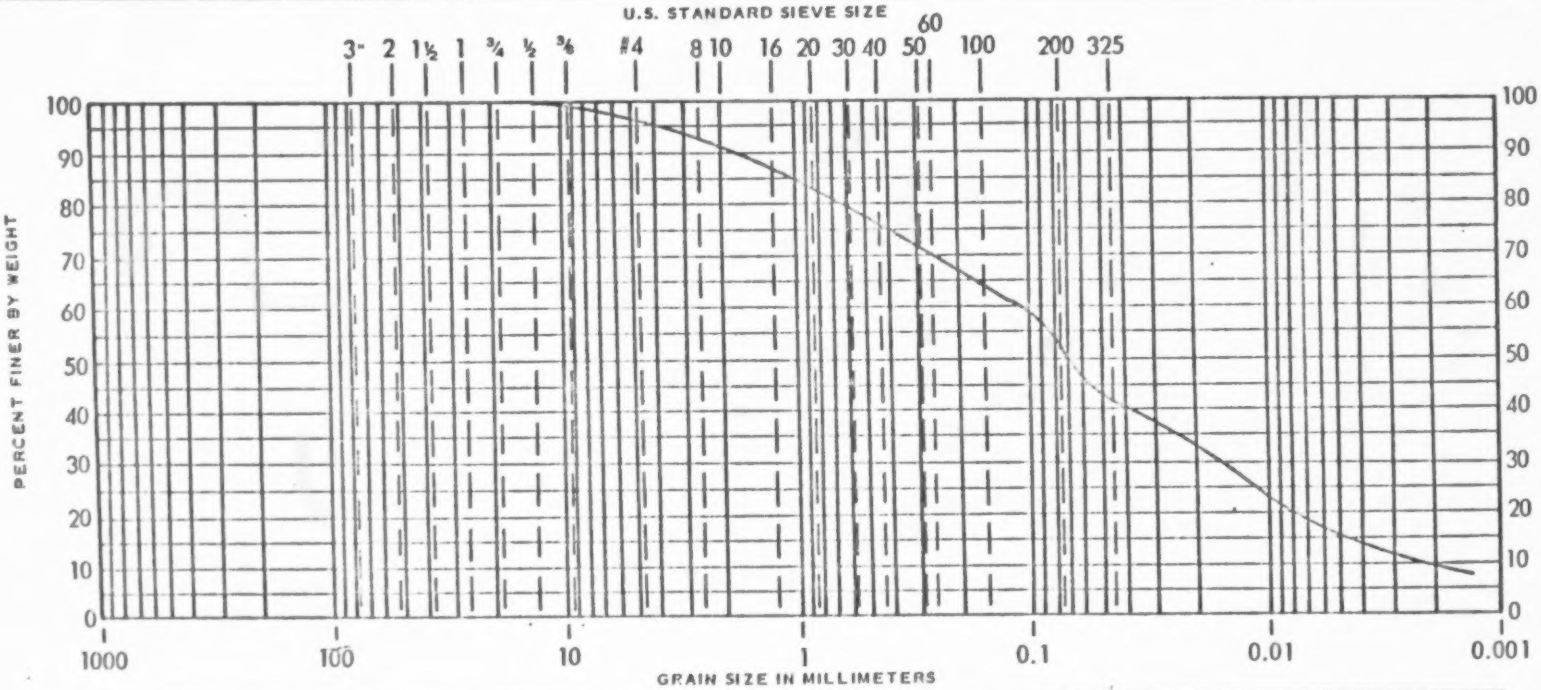
2A-34R

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 3%		SAND 40%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	42%	15%

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-6
SAMPLE NO. U8
DEPTH 64.0-66.0'
CLASSIFICATION "ML"
sandy "SILT"

NATURAL % MOISTURE 39.0
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S"

BOWSER-MORNER
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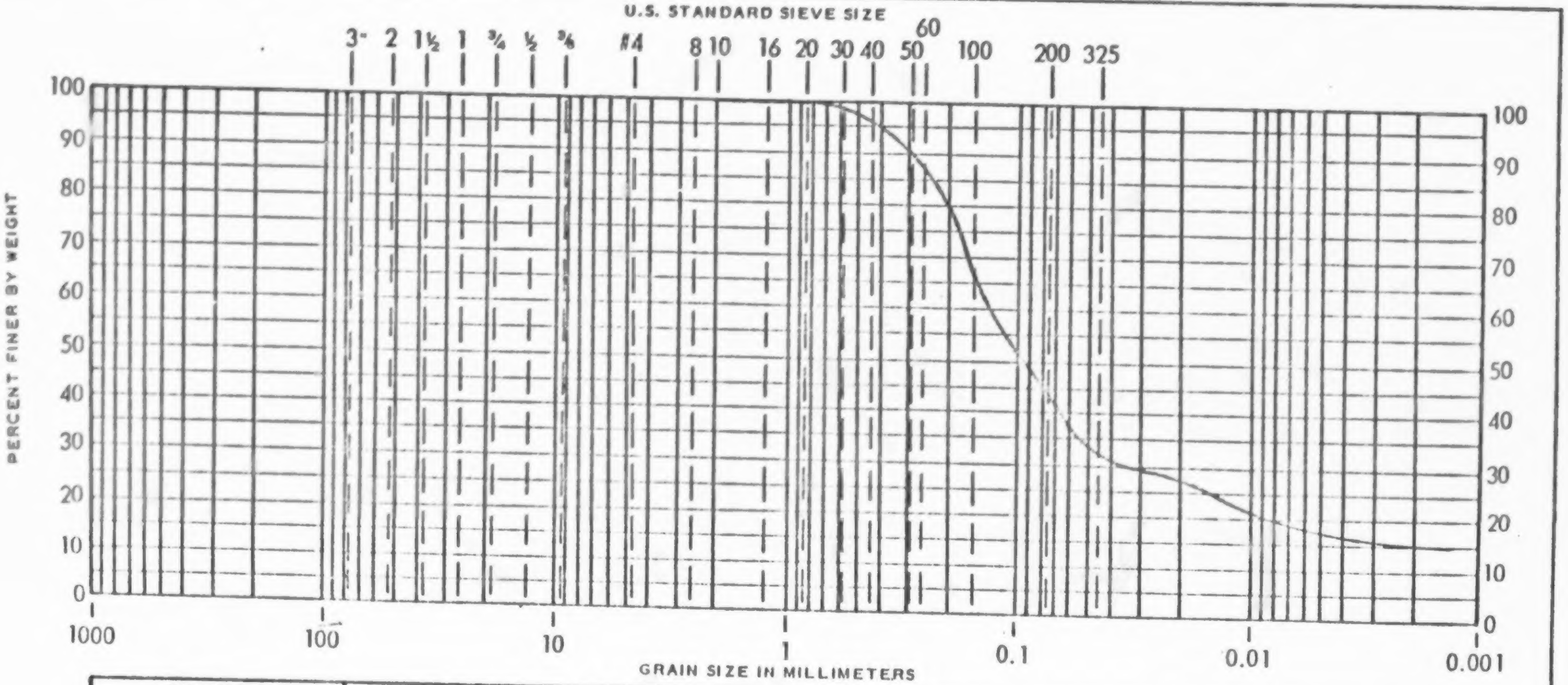
2A-34R

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 0%		SAND 58%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	25%	17%

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-9
SAMPLE NO. 3A
DEPTH 5.0-7.0'
CLASSIFICATION "SM"
silty "SAND"

NATURAL % MOISTURE 19.7
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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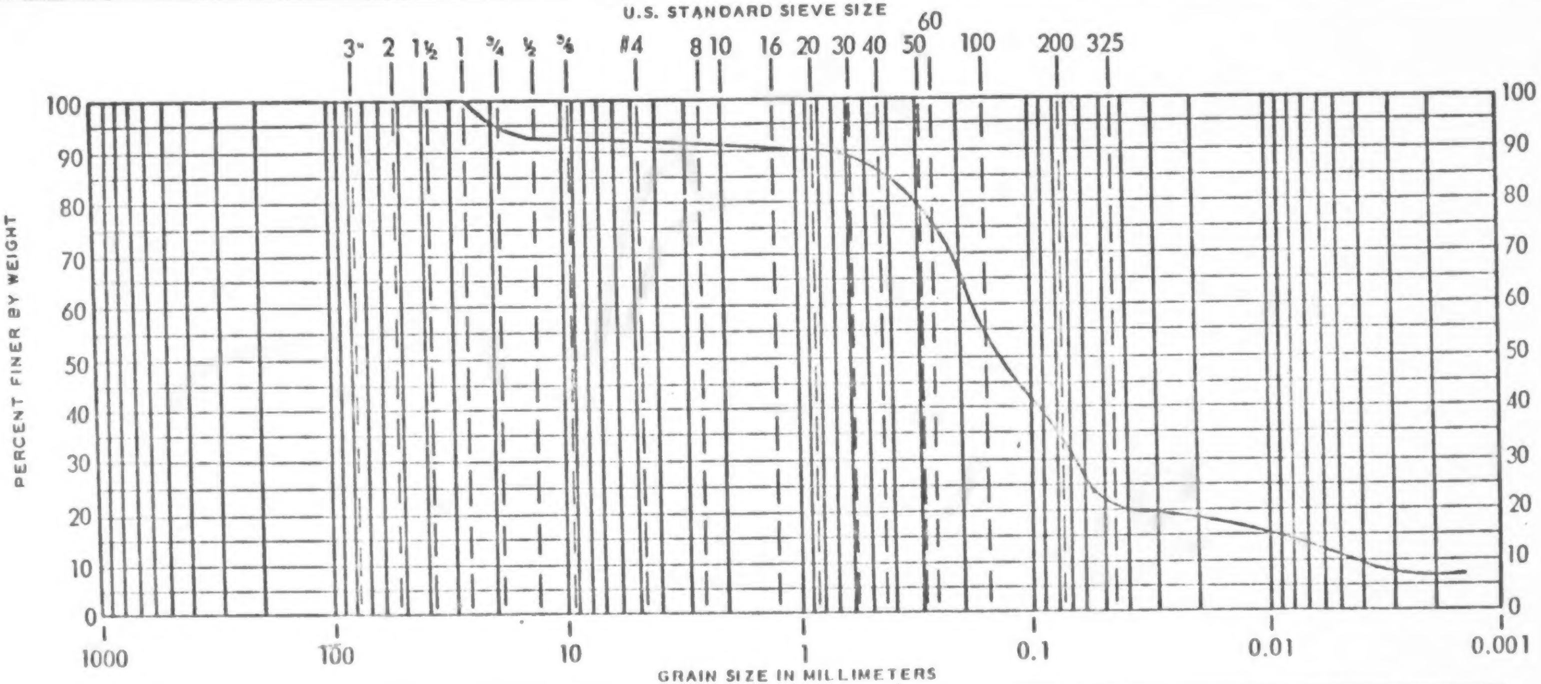

COBBLES	GRAVEL 9%		SAND 60%			SILT 21%	CLAY 10%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-9
SAMPLE NO. 15A
DEPTH 37.0-39.0'
CLASSIFICATION "SM"

silty "SAND"

NATURAL % MOISTURE Saturated
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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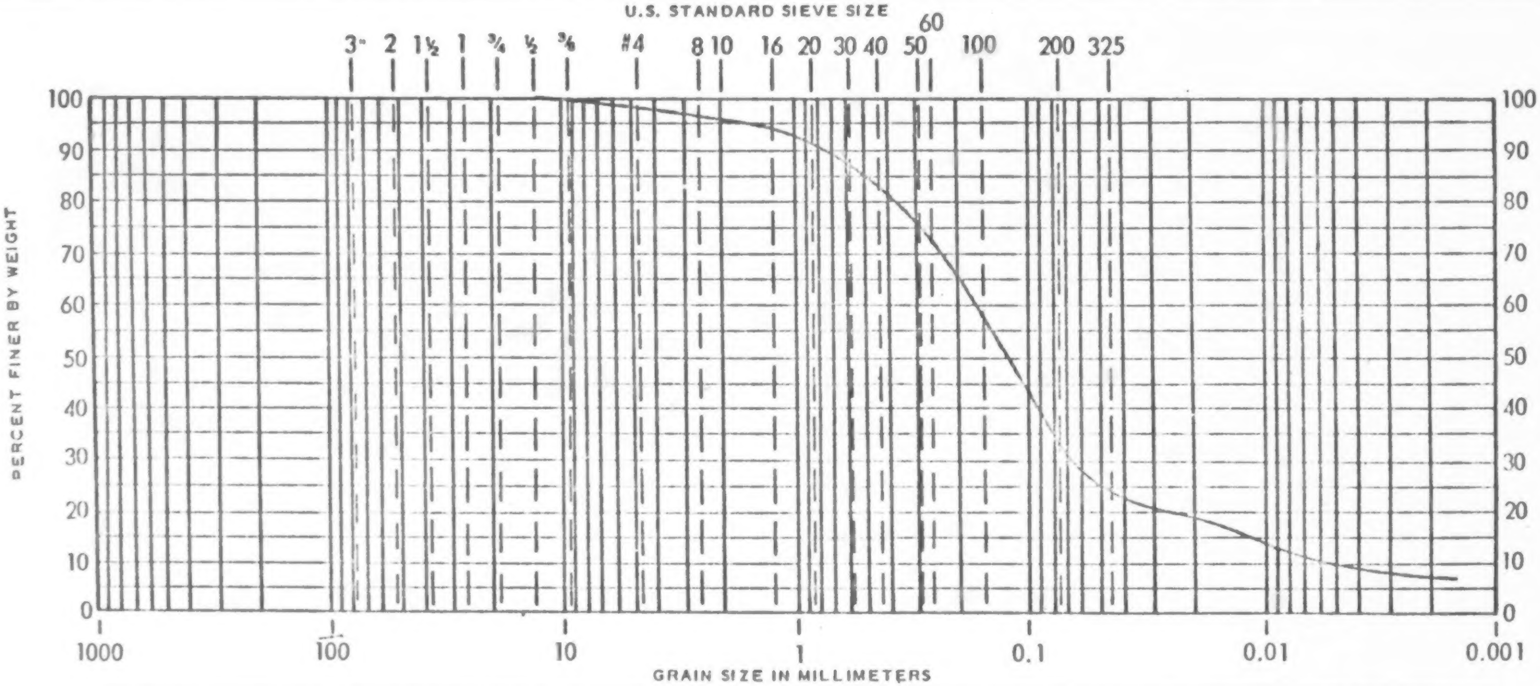

COBBLES	GRAVEL 1%		SAND 66%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	23%	10%

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-10
SAMPLE NO. 5A
DEPTH 19.0-21.0'
CLASSIFICATION "SM"
silty "SAND"

NATURAL % MOISTURE 22.9
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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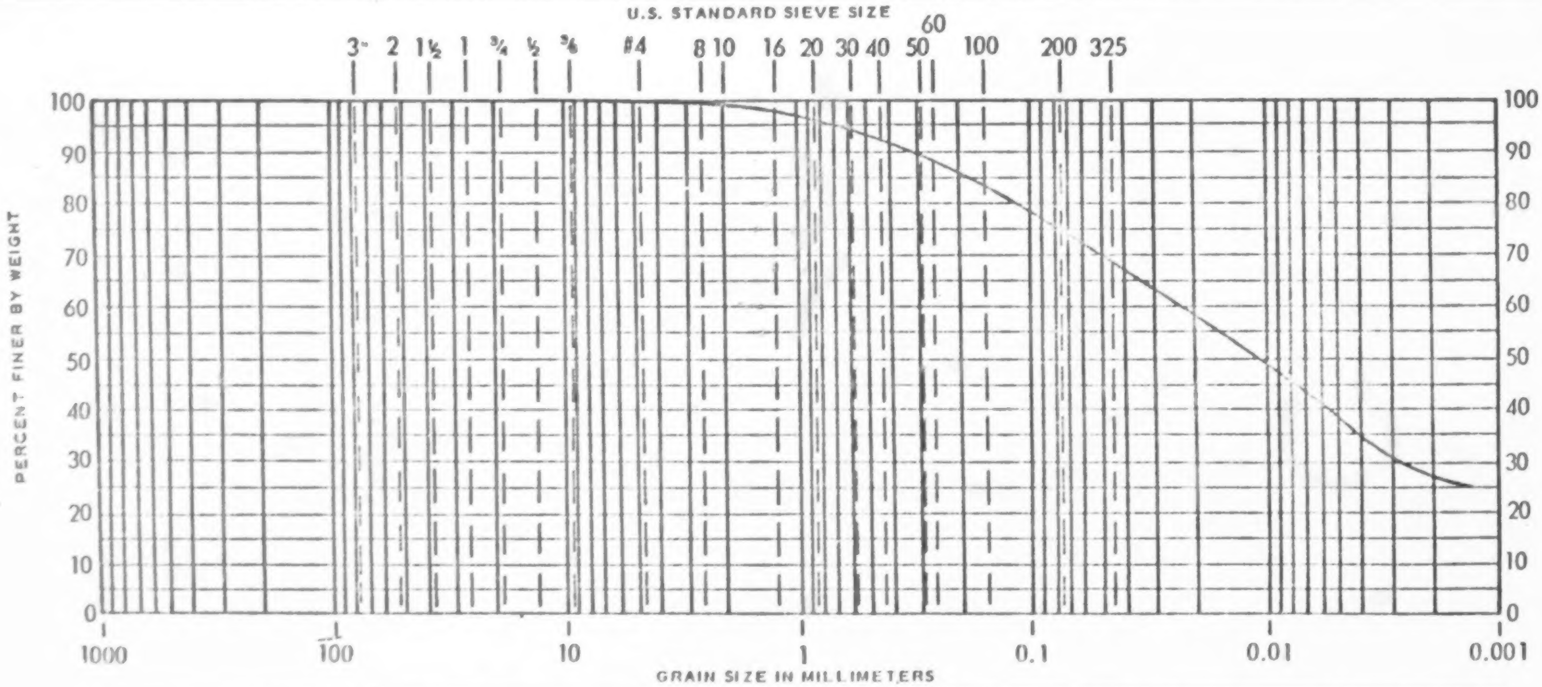

COBBLES	GRAVEL 1%		SAND 25%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	36%	38%

PROJECT	Arthur D. Little, New Elrama Disposal Site
BORING NO.	1-13
SAMPLE NO.	S-3
DEPTH	9.0-11.0'
CLASSIFICATION	"ML" sandy "SILT"

NATURAL % MOISTURE	34.2
LIQUID LIMIT	38
PLASTIC LIMIT	32
PLASTICITY INDEX	6
COLOR	Brown
REMARKS	"U.S.C.S."

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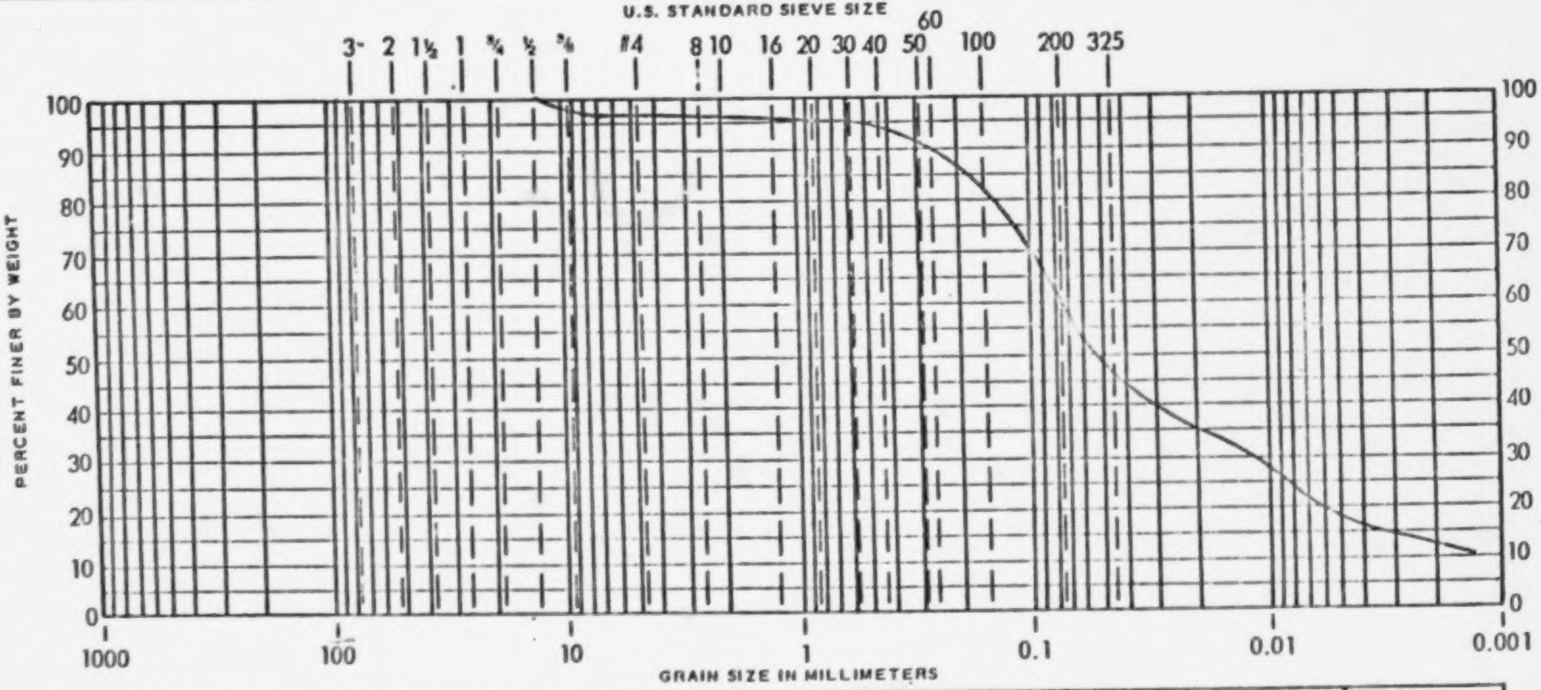
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 4%		SAND 34%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	45%	17%

PROJECT	Arthur D. Little, New Elrama Disposal Site
BORING NO.	1-14
SAMPLE NO.	S-6
DEPTH	24.0-26.0'
CLASSIFICATION	"ML" sandy "SILT"

NATURAL % MOISTURE	19.7
LIQUID LIMIT	Tested
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Reddish Lt. Brown
REMARKS	"U.S.C.S."

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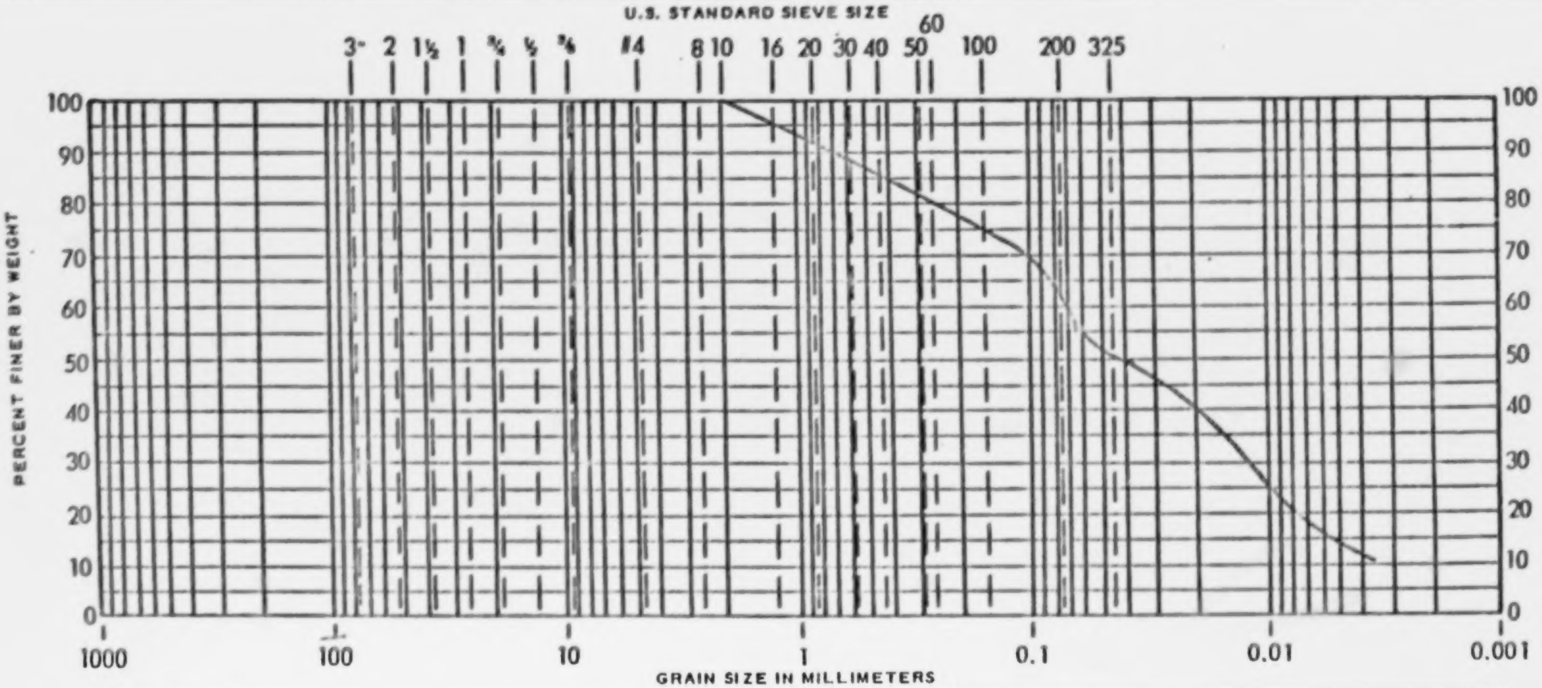
TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



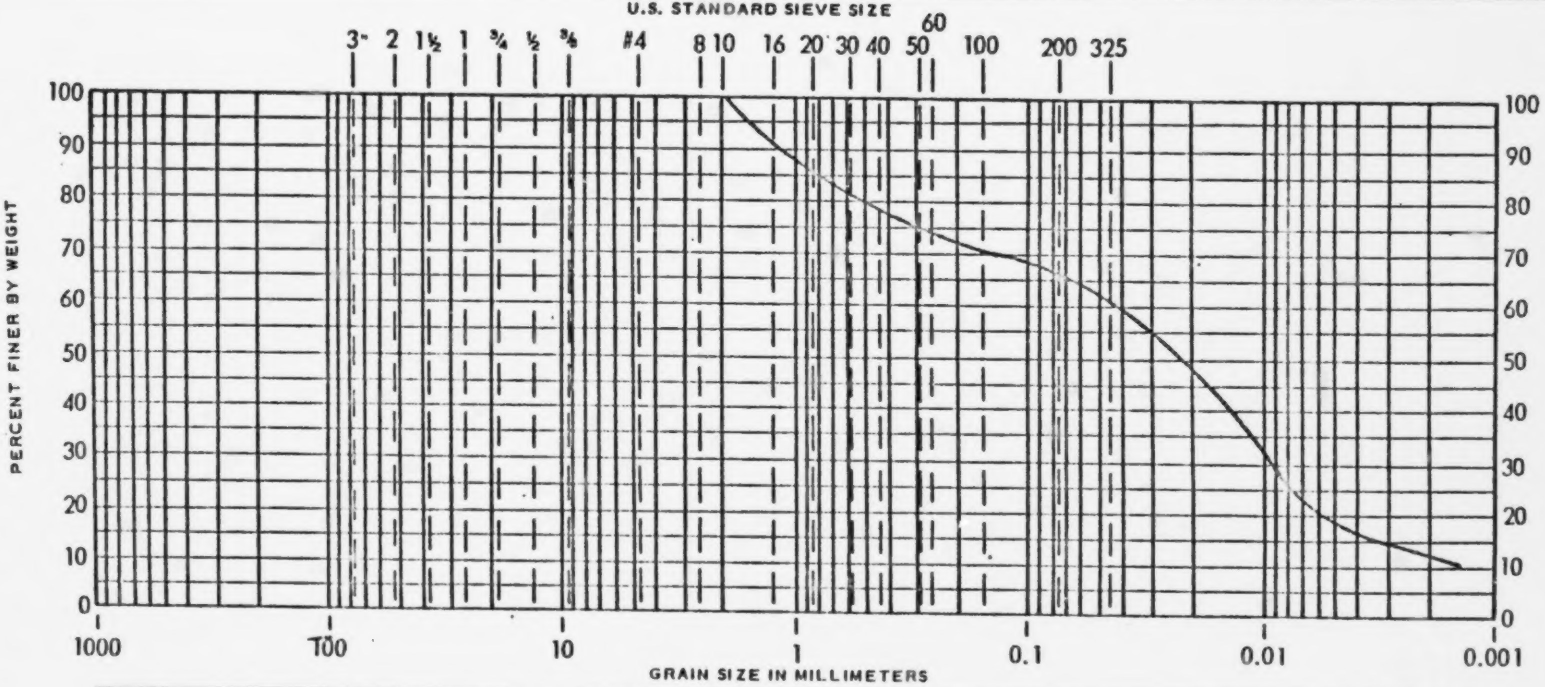
COBBLES	GRAVEL 0%		SAND 34%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	51%	15%

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-15
SAMPLE NO. 1U
DEPTH 13.0-15.0
CLASSIFICATION "ML"
sandy "SILT"

NATURAL % MOISTURE 26.5
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 0%		SAND 33%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	49%	18%

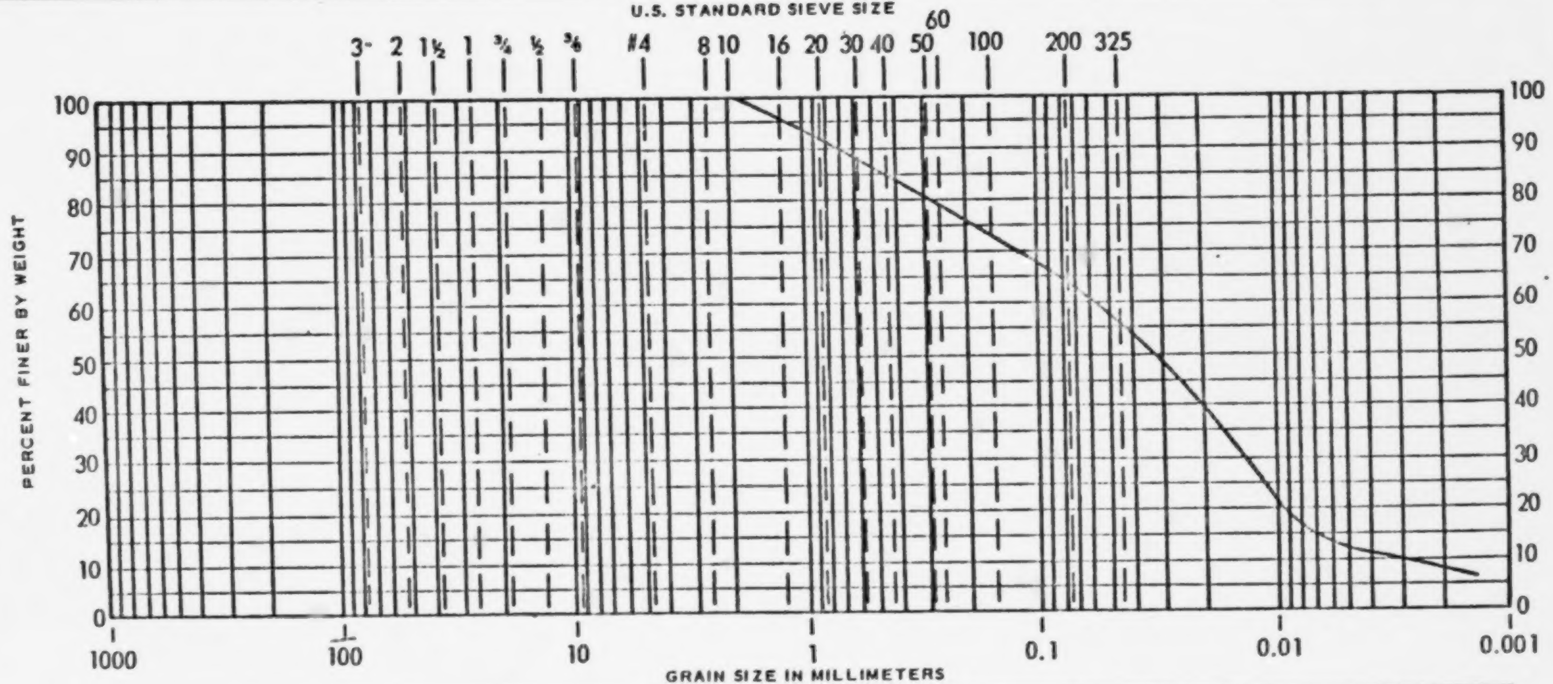
PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-15
SAMPLE NO. U2
DEPTH 17.0-18.5'
CLASSIFICATION "ML"
sandy "SILT"

NATURAL % MOISTURE 42.7
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 0%		SAND 36%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	51%	13%

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-15A
SAMPLE NO. 2U
DEPTH 10.0-12.0'
CLASSIFICATION "ML"
sandy "SILT"

NATURAL % MOISTURE 28.0
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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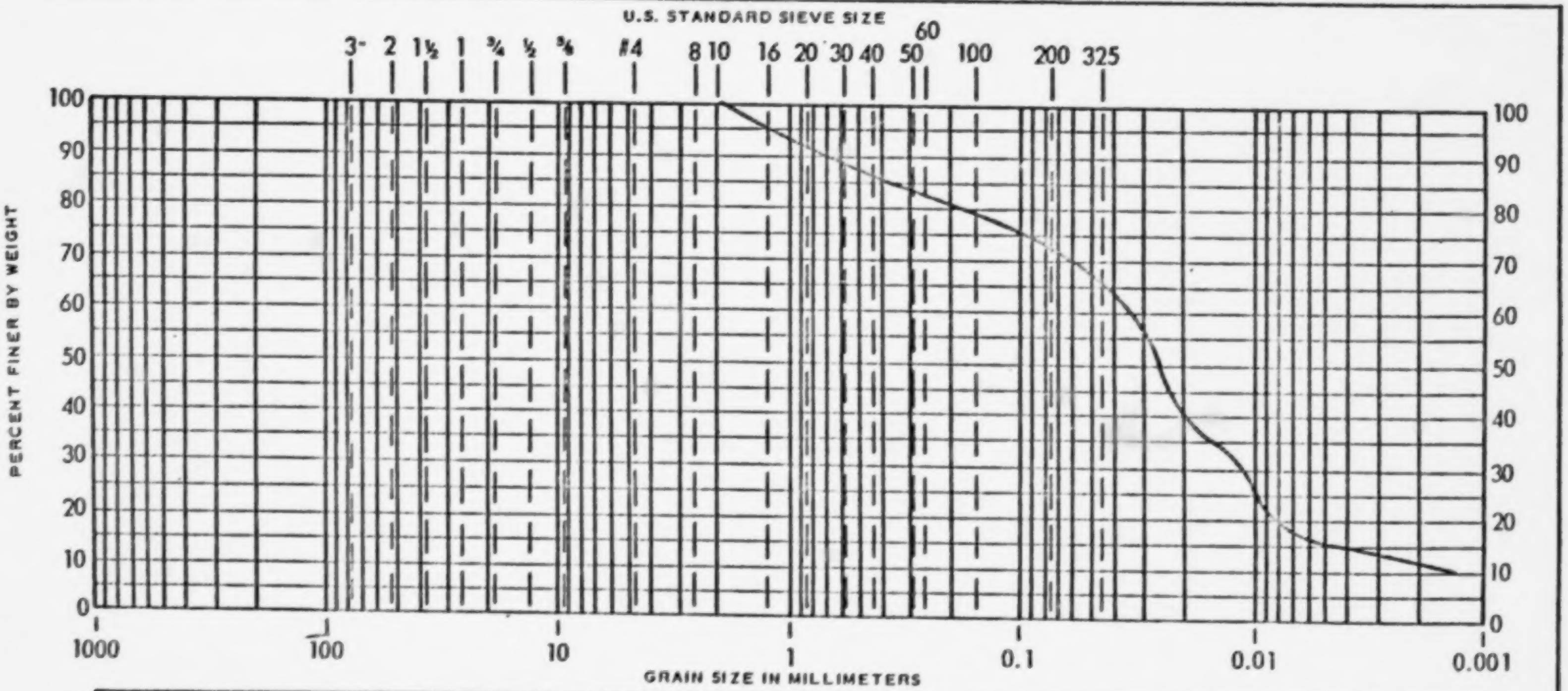
SOIL CLASSIFICATION SHEET



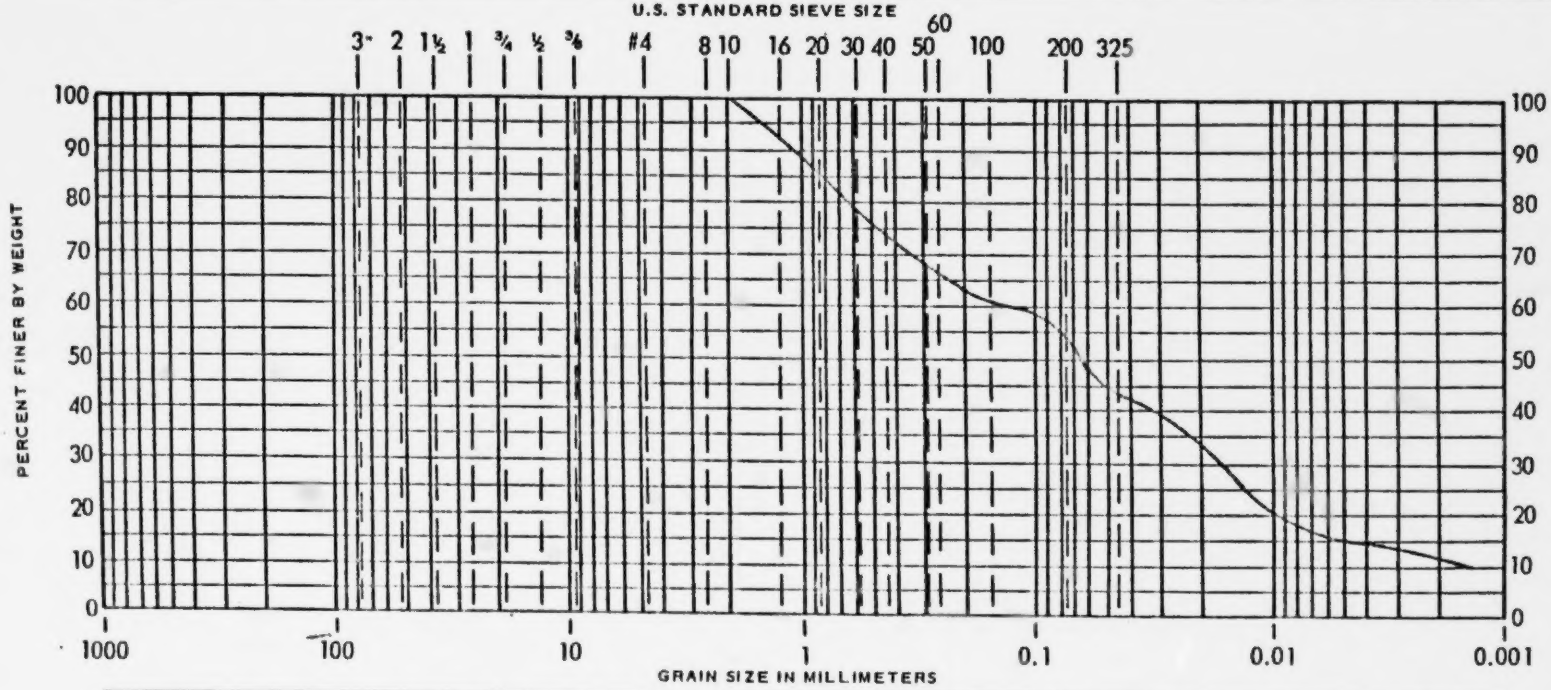
COBBLES	GRAVEL 0%		SAND 73%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	11%	16%

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. 1-15A
SAMPLE NO. U-3
DEPTH 13.0-15.0'
CLASSIFICATION "SM"
silty "SAND"

NATURAL % MOISTURE 55.6
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 0%		SAND 48%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	37%	15%

PROJECT Arthur D. Little, New Elrama Disposal Site

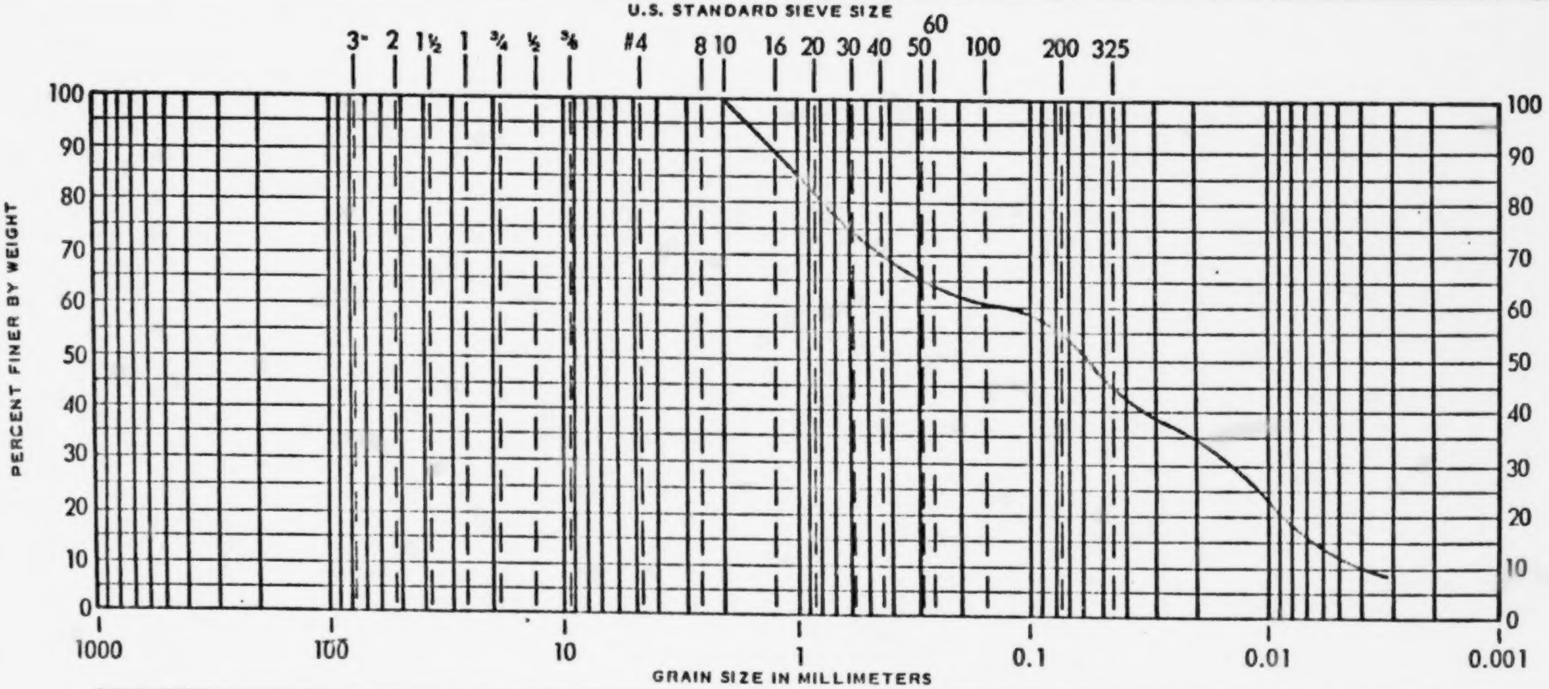
SAMPLE NO. Block Sample

CLASSIFICATION "ML"
silty "FINE SAND"

NATURAL % MOISTURE 30.8
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 0%		SAND 45%			SILT 34%	CLAY 11%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little, New Elrama Disposal Site
BORING NO. Bag Sample
SAMPLE NO. 11
DEPTH Point #2
CLASSIFICATION "ML"

silty "FINE SAND"

NATURAL % MOISTURE 0.25
LIQUID LIMIT
PLASTIC LIMIT
PLASTICITY INDEX 0
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

LABORATORY SUMMARY SHEET

Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Page 1 of 7

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
1-1	S1	0.0-0.6					6.3			
	S2	4.0-6.0					65.2			
	S3	9.0-11.0					12.3			
	S4	14.0-16.0					10.8			
	S5	16.0-18.0					17.5			
	S6	18.9-19.0					4.5			
1-2	S1	0.0-2.0					14.6			
	S2	4.0-6.0					31.1			
	S3	9.0-11.0					11.7			
	S4	14.0-16.0					11.3			
	S5	19.0-21.0					12.6			
	S6	23.5-24.0					9.0			
1-3	S1	4.5-6.5					19.0			
	S2	9.5-10.2					8.3			
	S3	14.5-15.0					16.7			
	S3A	15.0-15.5					42.4			
	S4	16.0-17.5					25.5			
	S4A	17.5-18.0					11.9			
	S5	18.0-20.0		48	40	8	34.2			"ML"
	S6	20.0-22.0					22.6			
	S7	22.0-24.0					22.3			
1-4	1A	1.0-3.0					19.8			
	2A	4.0-6.0					19.8			
	3A	9.0-11.0					21.4			
	4A	14.0-16.0					22.6			
	5A	19.0-21.0					21.5			
	6A	24.0-26.0					18.3			
	7A	29.0-31.0					Saturated			
	8A	34.0-36.0					20.9			
	9A	39.0-41.0					16.3			
	10A	44.0-46.0					Saturated			

LABORATO JMMARY SHEET

Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Page 2 of 7

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
	11A	49.0-51.0					7.1			
	12A	53.0-55.0					11.3			
1-5	1A	0.0-2.0					19.1			
	2A	4.0-6.0					21.5			
	3A	9.0-11.0					24.0			
	4A	14.0-16.0					12.3			
	5A	19.0-21.0					Saturated			
	6A	24.0-26.0					Saturated			
	7A	29.0-31.0					Saturated			
	8A	34.0-36.0					10.6			
	9A	39.0-41.0					10.0			
	10A	44.0-46.0					11.0			
	11A	47.0-47.2					10.4			
1-6	1U	2.5-4.0	Permeability				42.6	65.1		
	1U	2.5-4.0	Permeability	Tested Non Plastic			38.2	70.5		"SM"
	1S	4.0-8.0					43.3			
	2U	8.0-10.0	Permeability				29.0	60.2		
	2S	10.0-12.0					30.4			
	3U	12.0-14.0					----			
	3S	14.0-16.0					55.1			
	4S	16.0-18.0					----			
	5S	18.0-20.0					46.0			
	4U	20.0-22.0	Permeability	Tested Non Plastic			40.8	72.2		"ML"
	6S	22.0-24.0					34.8			
	7S	27.0-29.0					57.4			
	8S	32.0-34.0					41.4			
	5U	34.5-36.0					20.7			
	9S	36.0-38.0					34.3			
	10S	38.0-40.0					35.9			
	6U	40.0-41.5		Tested Non Plastic			20.7			"ML"
	11S	41.5-43.5					41.3			
	12S	43.5-45.0					39.9			
	13S	45.0-45.5					38.4			

LABORATORY SUMMARY SHEET

Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Page 3 of 7

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
	14S	46.5-48.0					31.5			
	15S	48.0-50.0					----			
	7U	50.0-50.5					----			
	16S	50.5-52.0		Tested Non Plastic			49.6			"ML"
	17S	52.0-54.0					44.2			
	18S	57.0-59.0					42.8			
	19S	62.0-64.0					46.7			
	8U	64.0-66.0	Permeability	Tested Non Plastic			39.0	64.6		"ML"
	9U	66.0-68.0					----			
	20S	68.0-70.0					64.9			
	21S	74.5-76.0					35.0			
	22S	79.5-81.5					----			
	23S	81.5-83.5					----			
	24S	83.5-85.5					22.8			
	25S	85.5-87.5					18.1			
	10U	87.5-90.0					----			
	26S	94.0-96.0					17.8			
	27S	99.0-101.0					18.4			
1-6A	1U	2.0-3.5					----			
	2U	20.0-22.0	Permeability				29.0	60.2		
	3U	23.0-25.0					----			
	4U	34.0-36.0					----			
	S1	48.0-50.0					----			
	U5	50.0-52.0					----			
	U6	52.0-52.5					----			
	S2	52.5-53.2					----			
1-7	S1	4.5-6.5					----			
	S2	8.5-10.5					----			
	S3	13.5-15.5					----			
	S4	18.5-20.5					----			

LABORATC UMMARY SHEET

Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Page 4 of 7

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
1-8	1A	1.0-3.0					22.2			
	2A	5.0-7.0					22.5			
	3A	10.0-12.0					17.6			
	4A	15.0-17.0					17.3			
	5A	20.0-22.0					9.1			
	6A	25.0-27.0					15.2			
	7A	30.0-32.0					18.3			
	8A	35.0-37.0					14.1			
	1C	40.0-41.1					----			
	9A	41.1-42.1					12.7			
	10A	45.0-45.5					23.0			
1-9	1A	0.0-2.0					23.5			
	2A	2.5-4.5					18.1			
	3A	5.0-7.0			Tested Non Plastic		19.7			"SM"
	4A	7.0-9.0					19.6			
	5A	9.5-11.5					24.1			
	6A	12.0-14.0					21.8			
	7A	14.5-16.5					17.1			
	8A	17.0-19.0					22.6			
	9A	19.5-21.5					22.7			
	10A	22.0-24.0					21.2			
	11A	24.5-26.5			Tested Non Plastic		Saturated			"SM"
	1C	27.0-29.5					----			
	12A	29.5-31.5					11.8			
	13A	32.0-34.0					13.5			
	14A	34.5-36.5					11.1			
	15A	37.0-39.0			Tested Non Plastic		Saturated			"SM"
	16A	39.5-41.5					19.6			
	17A	42.0-44.0					22.1			
	18A	46.5-47.5					10.2			

LABORATORY SUMMARY SHEET

Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S Soil Classificatio
1-10	1A	1.0-3.0					35.4			
	2A	4.0-6.0					30.8			
	3A	9.0-11.0					20.4			
	4A	14.0-16.0					15.5			
	5A	19.0-21.0			Tested Non Plastic		22.9			"SM"
	6A	24.0-26.0					28.0			
	7A	29.0-31.0					13.6			
	8A	34.0-35.5					8.6			
	9A	39.0-41.0					10.9			
	10A	44.0-46.0					14.5			
1-11	S1	0.0-2.0					22.9			
	S2	4.0-6.0					17.1			
	S3	9.0-11.0					19.1			
	S4	14.0-16.0					15.5			
	S5	19.0-21.0					13.1			
	S6	24.0-26.0					18.0			
	S7	29.0-31.0					14.0			
	S8	34.0-34.5					11.0			
	S9	39.0-39.1					----			
	S10	44.0-46.0					----			
1-12	S1	0.0-1.5					13.4			
	S1A	1.5-2.0					19.7			
	S2	4.0-6.0					43.6			
	S3	9.0-11.0					31.1			
	S4	14.0-16.0					56.2			
	S5	19.0-20.0					55.8			
	S5A	20.0-21.0					18.7			
	S6	24.0-26.0					15.5			
	S7	29.0-31.0					17.0			
	S8	34.0-35.0					11.2			
	S8A	35.0-36.0					----			

LABORATORY SUMMARY SHEET

Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
	10S	41.0-43.0					----			
	11S	44.0-46.0					----			
	13S	54.0-56.6					----			
	14S	59.0-61.0					----			
1-12A	S1	14.5-16.5					----			
1-13	S2	9.0-11.0					----			
	S3	14.0-16.0		38	32	6	34.2			"ML"
	S4	19.0-20.0					----			
	S4A	20.0-21.0					----			
	S5	24.0-26.0					----			
	S6	29.0-31.0					----			
	S7	34.0-36.0					----			
	S8	39.0-41.0					----			
	S9	44.0-46.0					----			
	S10	49.0-51.0					----			
	S11	54.0-54.5					----			
1-13A	1S	18.0-20.0					----			
1-14	S1	0.0-2.0					26.8			
	S2	4.0-6.0					15.7			
	S3	9.0-11.0					21.4			
	S4	14.0-16.0					17.7			
	S5	19.0-21.0					14.7			
	S6	24.0-26.0		Tested Non Plastic			19.7			"ML"
	S7	29.0-31.0					----			
	S8	34.0-34.5					----			
1-15	S1	4.5-6.5					----			
	S2	9.5-11.5					19.8			

LABORATO[illegible] SUMMARY SHEET

Arthur D. Little, New Elrama Disposal Site, Pennsylvania

Page 7 of 7

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
	U1	13.0-15.0	Permeability	Tested	Non	Plastic	49.6	49.6		"ML"
	S3	15.0-17.0					19.9			
	U2	17.0-18.5	Permeability	Tested	Non	Plastic	49.4	64.1		"ML"
	S4	18.5-20.5					26.9			
	S5	24.5-26.5					17.2			
	S6	29.5-31.5					26.3			
	U3	31.5-33.0		Tested	Non	Plastic	55.6			"SM"
	S7	34.5-36.5					28.4			
	U4	36.5-38.51	Permeability				26.8	92.4		
	S8	39.0-41.0					12.1			
	S9	42.0-44.0					----			
	S10	46.5-48.0					----			
	S11	49.5-51.5					12.5			
	S12	54.5-56.5					----			
	S13	59.5-61.5					----			
	S14	64.5-66.5					16.7			
	S15	69.5-71.5					11.6			
	S16	74.5-76.5					14.6			
	S17	79.5-81.5					16.7			
	S18	89.5-91.5					14.0			
	S19	95.5-96.0					----			
1-15A	1U	4.0-6.0					----			
	2U	10.0-12.0		Tested	Non	Plastic	28.0			"ML"
	3U	13.0-15.0	Permeability	Tested	Non	Plastic	62.6	54.3		"SM"
	4U	18.0-19.5					----			
	5U	19.5-21.0					----			
	S1	23.5-24.0					----			
	6U	24.0-25.0					----			
Block Samples	2	----	Permeability				50.4	62.2		
	4	----	Permeability				51.1	60.9		
	8	----	Permeability				50.8	61.9		

Dave Johnston Pacific P&L

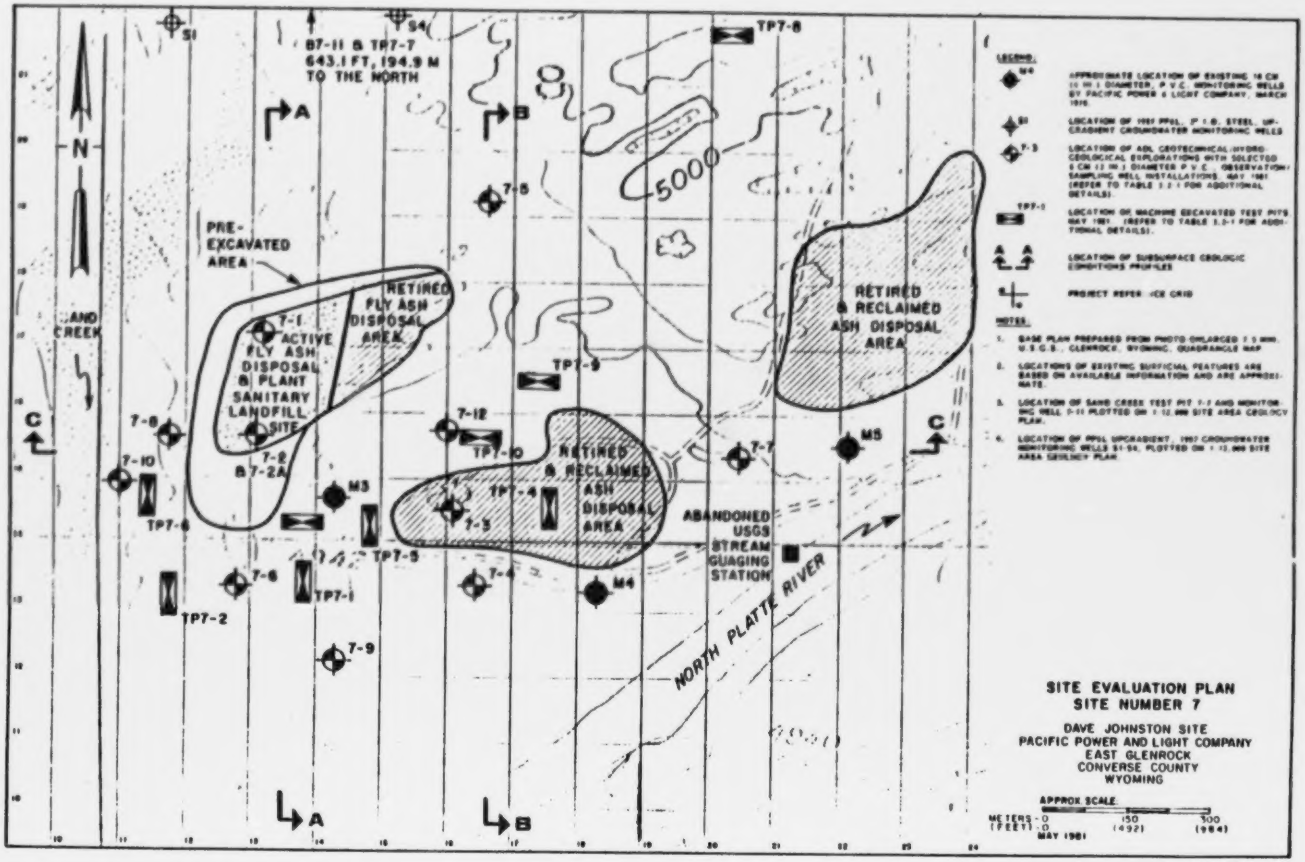

N
SAND CREEK
S1
S4
B7-11 & TP7-7
643.1 FT, 194.9 M
TO THE NORTH
A
B
C
8
5000
PRE-EXCAVATED AREA
RETIRED FLY ASH DISPOSAL AREA
ACTIVE FLY ASH DISPOSAL & PLANT SANITARY LANDFILL SITE
7-1
7-2
B7-2A
7-8
7-10
TP7-6
TP7-2
7-6
M3
TP7-1
TP7-5
7-9
7-5
7-12
TP7-10
TP7-9
TP7-4
7-3
7-4
RETIRED & RECLAIMED ASH DISPOSAL AREA
M4
ABANDONED USGS STREAM GUAGING STATION
NORTH PLATTE RIVER
7-7
M5
TP7-8
RETIRED & RECLAIMED ASH DISPOSAL AREA
LEGEND:
M4
APPROXIMATE LOCATION OF EXISTING 10 CM (4 IN.) DIAMETER, P.V.C. MONITORING WELLS BY PACIFIC POWER & LIGHT COMPANY, MARCH 1978.
S1
LOCATION OF 1981 PP&L, 5" I.D. STEEL, UP-GRADIENT GROUNDWATER MONITORING WELLS
7-3
LOCATION OF ADL GEOTECHNICAL/HYDROGEOLOGICAL EXPLORATIONS WITH SELECTED 5 CM (2 IN.) DIAMETER P.V.C. OBSERVATION/SAMPLING WELL INSTALLATIONS, MAY 1981 (REFER TO TABLE 3.2-1 FOR ADDITIONAL DETAILS).
TP7-1
LOCATION OF MACHINE EXCAVATED TEST PITS MAY 1981. (REFER TO TABLE 3.3-1 FOR ADDITIONAL DETAILS).
A A
LOCATION OF SUBSURFACE GEOLOGIC CONDITIONS PROFILES
PROJECT REFERENCE GRID
NOTES:
1. BASE PLAN PREPARED FROM PHOTO ENLARGED 7.5 MIN. U.S.G.S., GLENROCK, WYOMING, QUADRANGLE MAP
2. LOCATIONS OF EXISTING SURFICIAL FEATURES ARE BASED ON AVAILABLE INFORMATION AND ARE APPROXIMATE.
3. LOCATION OF SAND CREEK TEST PIT 7-7 AND MONITORING WELL 7-11 PLOTTED ON 1:12,000 SITE AREA GEOLOGY PLAN.
4. LOCATION OF PP&L UPGRADIENT, 1981 GROUNDWATER MONITORING WELLS S1-S4, PLOTTED ON 1:12,000 SITE AREA GEOLOGY PLAN.
SITE EVALUATION PLAN
SITE NUMBER 7
DAVE JOHNSTON SITE
PACIFIC POWER AND LIGHT COMPANY
EAST GLENROCK
CONVERSE COUNTY
WYOMING
APPROX SCALE
METERS 0 150 300
(FEET) 0 (492) (984)
MAY 1981

FIGURE 5.22

UNIVERSITY OF LOUISVILLE
LOUISVILLE, KENTUCKY ~~40208~~ 40292

SPEED SCIENTIFIC SCHOOL
JAMES BRECKENRIDGE SPEED FOUNDATION
DEPARTMENT OF CIVIL ENGINEERING

February 1, 1982

MEMO TO: C. J. Santhanam, ADL

FROM. .: C. R. Ullrich CR Ullrich

SUBJECT: QA/QC Physical Property Tests

Please find attached a summary of results of QA/QC physical property tests performed by University of Louisville personnel on waste samples obtained from the Dave Johnson site. Samples consisted entirely of ash materials contained in a single 24-inch-long, 3-inch-diameter Shelby tube. Test results are reported for permeability tests performed on remolded compacted samples of the ash. Unconfined compression tests could not be performed because of the friable nature of the samples.

QA/QC samples from the Powerton site are expected soon. Results of tests will be forwarded to you as they become available.

SUMMARY OF RESULTS

QA/QC PHYSICAL PROPERTY TESTS

DAVE JOHNSON SITE

Boring No.: 7-2

Sample No.: 5C

Depth: 24.0' - 26.0'

Date of sampling: May 25, 1981

Results of permeability tests on remolded, compacted samples

Depth Interval (ft.)	Material	Water Content (%)	Moist Density (pcf)	Dry Density (pcf)	Coefficient of Permeability (cm/sec)
24.0'-24.5'	ash*	5.85	112.9	106.7	1.03×10^{-3}
24.5'-25.0'	ash	7.82	75.5	69.9	1.47×10^{-4}
25.5'-26.0'	ash	11.25	76.6	68.6	1.95×10^{-4}

*Ash contained in the depth interval from 24.0 ft to 24.5 ft was visibly coarser and different in color and consistency than ash contained in the depth interval from 24.5 ft to 26.0 ft. One sample from the 24.0 - 24.5-ft interval was tested and two samples from the 24.5 - 26.0-ft interval were tested.

BOWSER-MORNER
TESTING LABORATORIES, INC.
P. O. Box 51
DAYTON, OHIO 45401

(513) 253-8805

LETTER OF TRANSMITTAL

DATE Sept 24, 1981
JOB NO.
ATTENTION
RE:

TO Arthur D. Little, Inc.
20 Acorn Park
Cambridge, Mass. 02140
Attn: Mr. Dave Kleinschmidt

GENTLEMEN:

WE ARE SENDING YOU ☐ Attached ☐ Under separate cover via __________ the following items:

☐ Shop drawings ☐ Prints ☐ Plans ☐ Samples ☐ Specifications

☐ Copy of letter ☐ Change order ☐ __________

COPIES	DATE	NO.	DESCRIPTION

THESE ARE TRANSMITTED as checked below:

☐ For approval ☐ Approved as submitted ☐ Resubmit _____ copies for approval

☐ For your use ☐ Approved as noted ☐ Submit _____ copies for distribution

☐ As requested ☐ Returned for corrections ☐ Return _____ corrected prints

☐ For review and comment ☐ __________

☐ FOR BIDS DUE __________ 19_____ ☐ PRINTS RETURNED AFTER LOAN TO US

REMARKS Laboratory data for the Dave Johnson site.

COPY TO __________

E-118

SIGNED: __________

If enclosures are not as noted, kindly notify us at once.

Constant Head Permeability Test

Project: Arthur D. Little, Johnston Site

Boring No.:	7-1
Sample No.:	4C
Depth Interval of Sample:	18.5' - 20.5'
Depth Interval of Test Specimen:	20.0' - 20.2'
SPECIMEN DATA:	
Dimensions, inches,	
Height:	2.212
Diameter:	2.824
Weight, lbs.,	
Initial:	0.59
Moisture Content, %:	
Initial:	10.9
Final:	37.2
Wet Unit Weight, pcf,	
Initial:	73.6
Final:	91.0
Dry Unit Weight, pcf,	
Initial:	66.4
Back Pressure Saturation, psi,	
Pressures:	10.0
Material Description:	Gray Flyash
Permeability, cm/sec,	
k:	2×10^{-5}

Constant Head
Permeability Test

Project: Arthur D. Little, Johnston Site

Boring No.: 7-2

Sample No.: 1C

Depth Interval of Sample: 4.5' - 6.5'

Depth Interval of Test Specimen: 5.0' - 5.2'

SPECIMEN DATA:

Dimensions, inches,

Height: 2.832

Diameter: 2.627

Weight, lbs.,

Initial: 0.64

Moisture Content, %:

Initial: 12.1

Final: 34.0

Wet Unit Weight, pcf,

Initial: 72.0

Final: 86.1

Dry Unit Weight, pcf,

Initial: 64.3

Back Pressure Saturation, psi,

Pressures: 10.0

Material Description: Gray Flyash

Permeability, cm/sec,

k: 5 x 10^{-5}

Constant Head

Permeability Test

Project: Arthur D. Little, Johnston Site

Boring No.: 7-2

Sample No.: 3C

Depth Interval of Sample: 11.5' - 13.5'

Depth Interval of Test Specimen: 13.0' - 13.2'

SPECIMEN DATA:

Dimensions, inches,

Height: 2.370

Diameter: 2.896

Weight, lbs.,

Initial: 0.70

Moisture Content, %:

Initial: 5.4

Final: 35.1

Wet Unit Weight, pcf,

Initial: 77.5

Final: 99.3

Dry Unit Weight, pcf,

Initial: 73.5

Back Pressure Saturation, psi,

Pressures: 10.0

Material Description: Gray Flyash

Permeability, cm/sec,

k: 2 x 10^{-7}*

---

*Sample not representative based on data from surroundings.

Constant Head

Permeability Test

Project: Arthur D. Little, Johnston Site

Boring No.: 7-3A

Sample No.: 1C

Depth Interval of Sample: 5.8' - 7.2'

Depth Interval of Test Specimen: 6.0' - 6.2'

SPECIMEN DATA:

Dimensions, inches,

Height: 2.000

Diameter: 2.788

Weight, lbs.,

Initial: 0.57

Moisture Content, %:

Initial: 22.9

Final: 37.7

Wet Unit Weight, pcf,

Initial: 80.7

Final: 90.4

Dry Unit Weight, pcf,

Initial: 65.6

Back Pressure Saturation, psi,

Pressures: 10.0

Material Description: Gray Flyash

Permeability, cm/sec,

k: 6×10^{-5}

BOWSER-MORNER Testing Laboratories, Inc.

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TOLEDO DISTRICT • 122 S. St. Clair St. • P.O. Box 838 • Toledo, Ohio 43696 • 419/255-8200
KENTUCKY DISTRICT • Route 8 West • P.O. Box 636 • Maysville, Kentucky 41056 • 606/564-6711

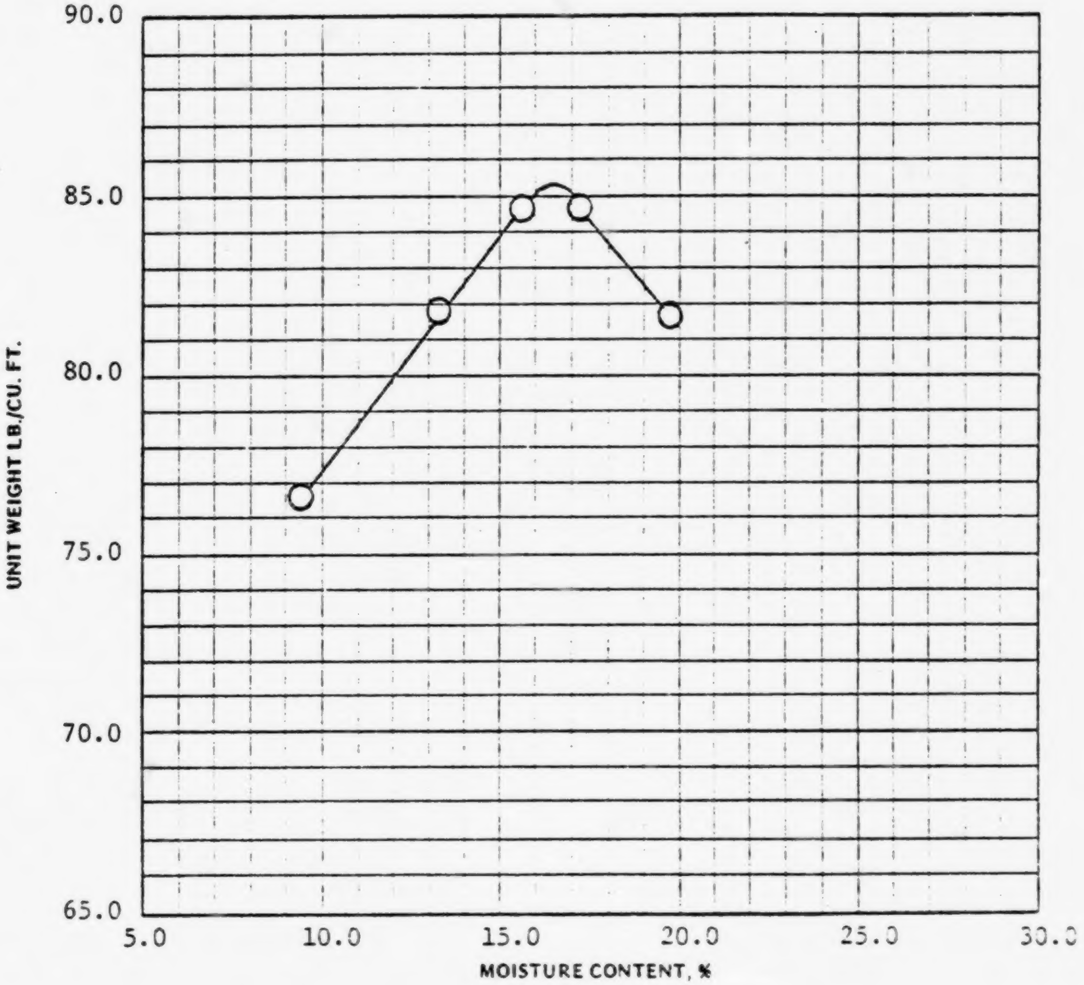
REPORT OF PROCTOR CURVE

CLIENT: Arthur D. Little Company

PROJECT: Johnston Site

MATERIAL: Flyash

SOURCE OF MATERIAL: Jobsite



Type Proctor ASTM D-698-70-Method C

Maximum Dry Density 85.3 Lbs./cu. ft. Optimum Moisture Content 16.5 % *

* 140°F

Respectfully submitted.

EXTENDED PERMEABILITY TEST

Project: Arthur D. Little, Johnston Site

Boring No.: 7-2

Sample No.: 6C

Depth: 29.0' - 31.0'

Material: Flyash

SPECIMEN DATA

Initial Conditions,

Height: 5.365"
Diameter: 2.748"
Weight: 1.30 lbs.
Moisture Content: 2.3%
Specific Gravity: 2.32
Wet Unit Weight: 70.6 pcf
Dry Unit Weight: 69.0 pcf

Test Summary
Graphical Presentation on Following Pages

Dry Unit Weight pcf	Permeability, k 10^{-4} cm/sec
69.0	4.9
70.7	5.1
72.7	4.4
74.5	3.9
75.8	3.1

K+E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN USA

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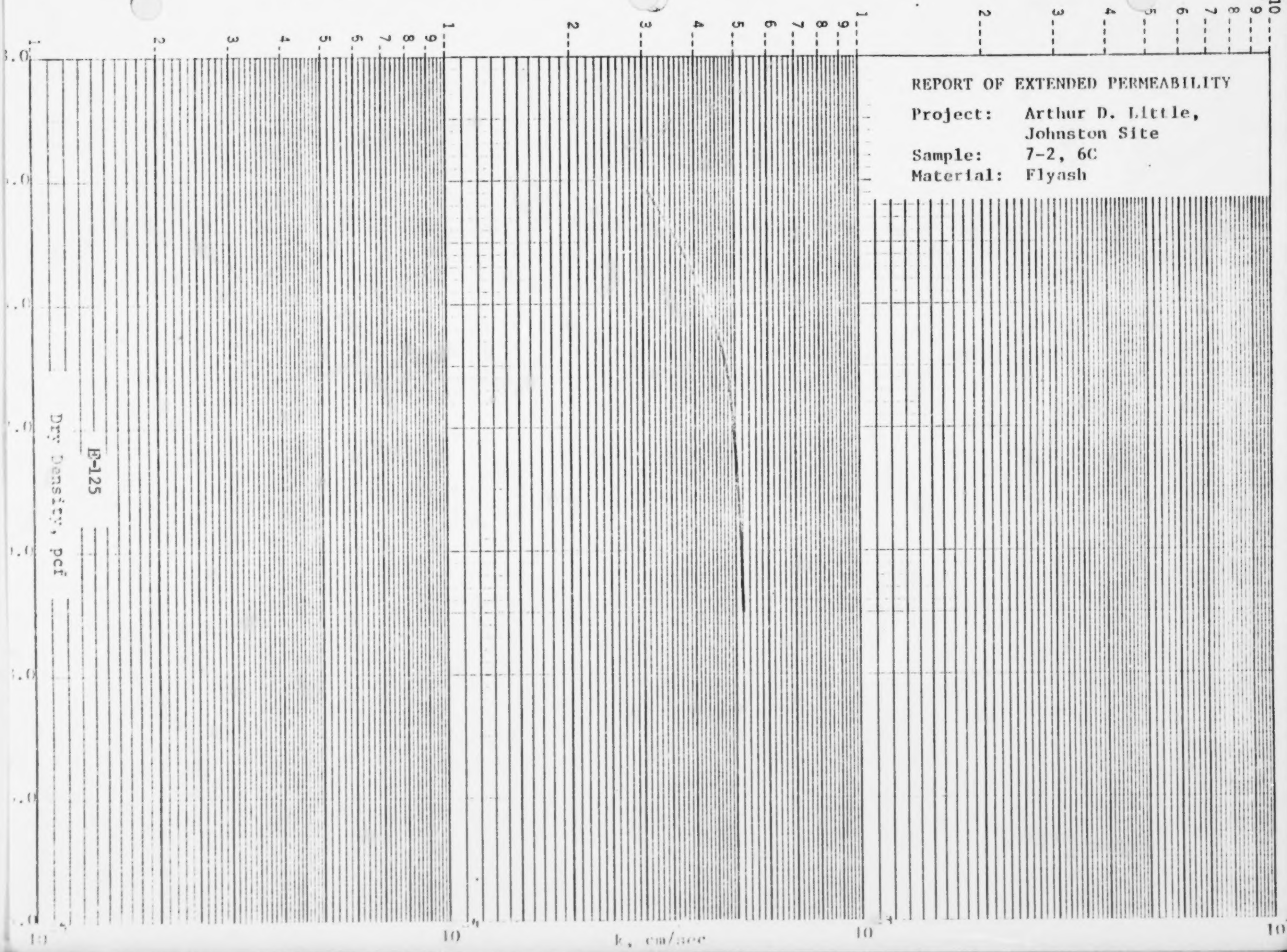


REPORT OF EXTENDED PERMEABILITY

Project: Arthur D. Little,
Johnston Site
Sample: 7-2, 6C
Material: Flyash

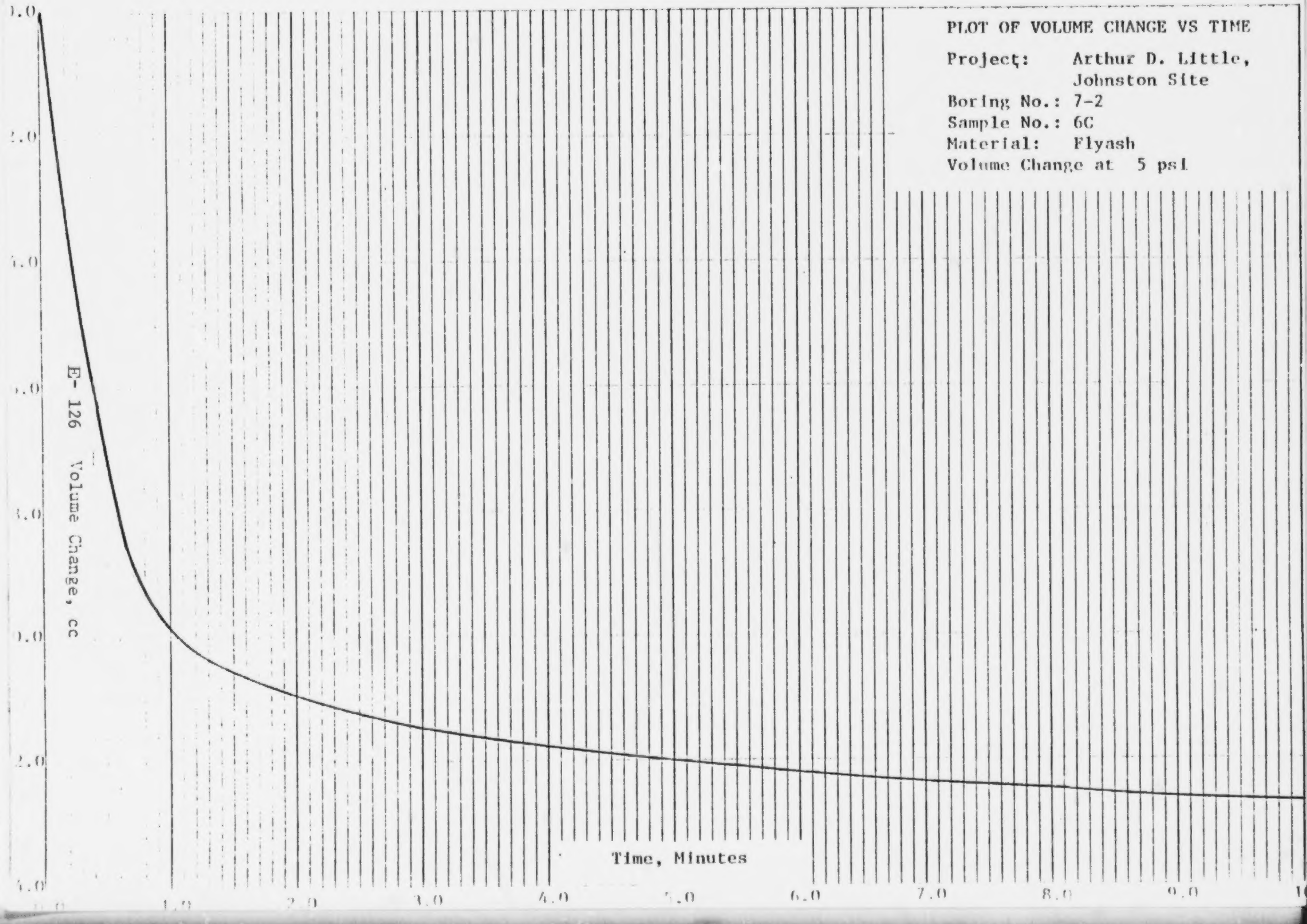
E-125

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO MADE IN U.S.A.

46 0700

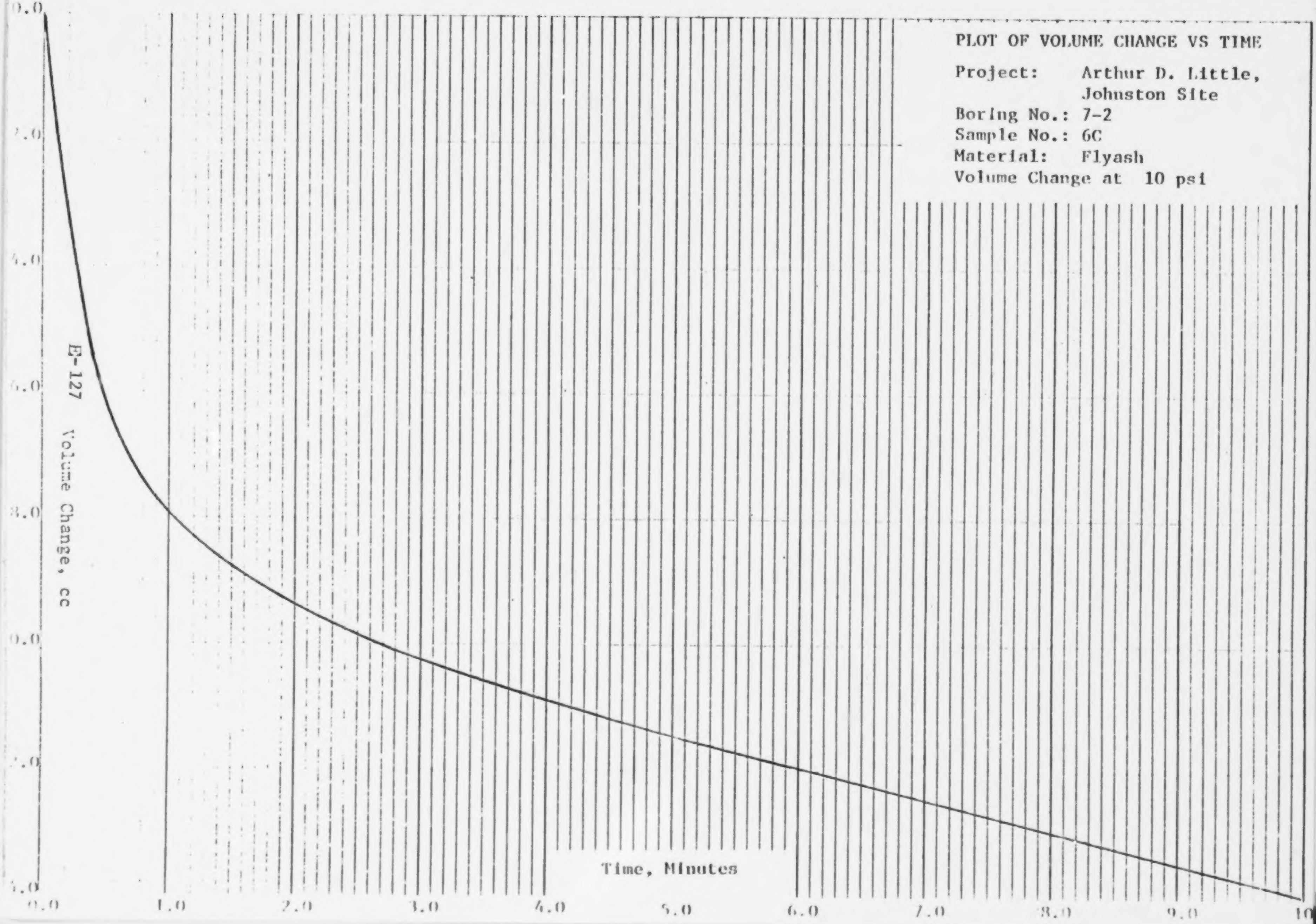
PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little,
Johnston Site
Boring No.: 7-2
Sample No.: 6C
Material: Flyash
Volume Change at 5 psi



K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0700



PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little,
Johnston Site
Boring No.: 7-2
Sample No.: 6C
Material: Flyash
Volume Change at 10 psi

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
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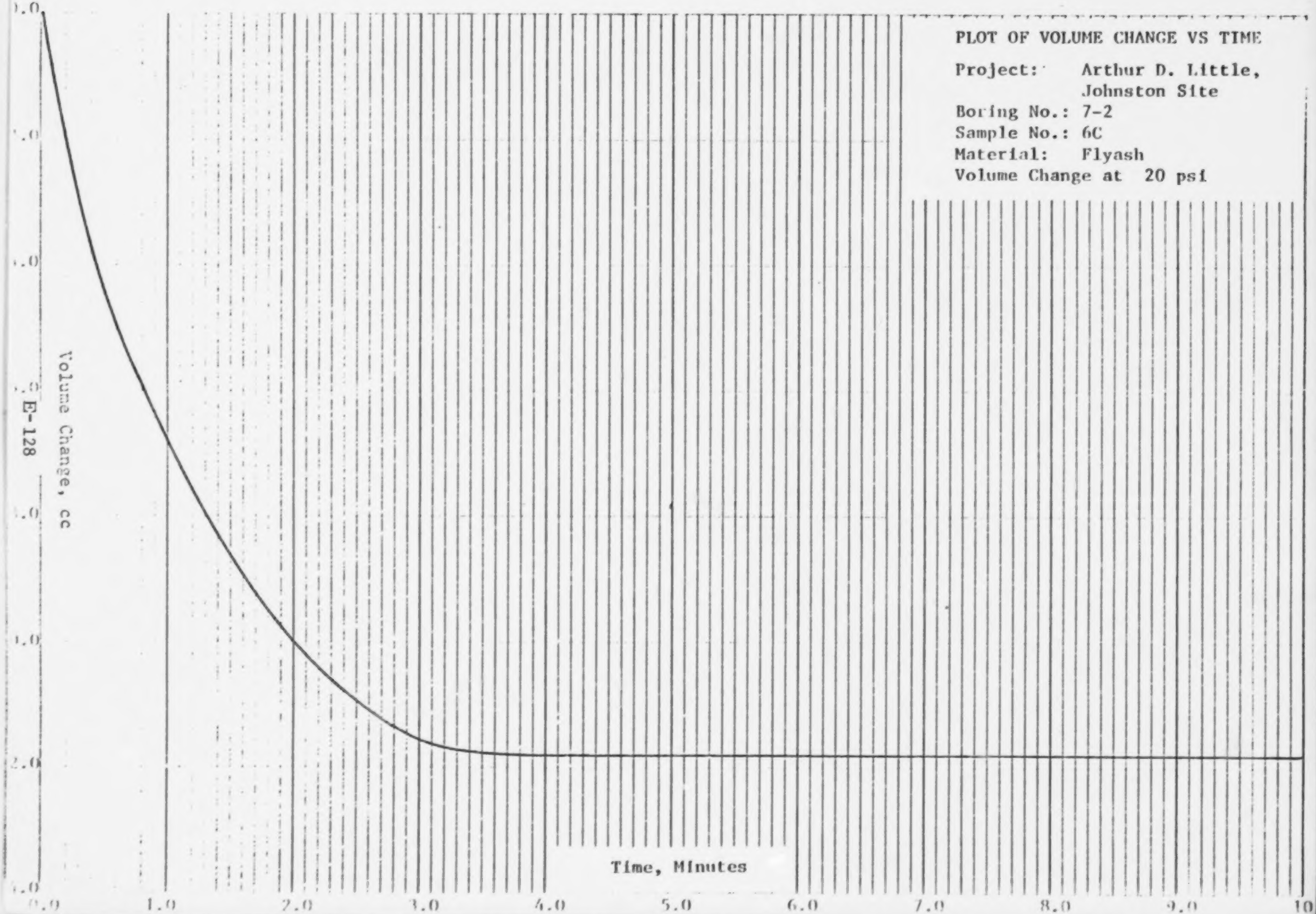
46 0700

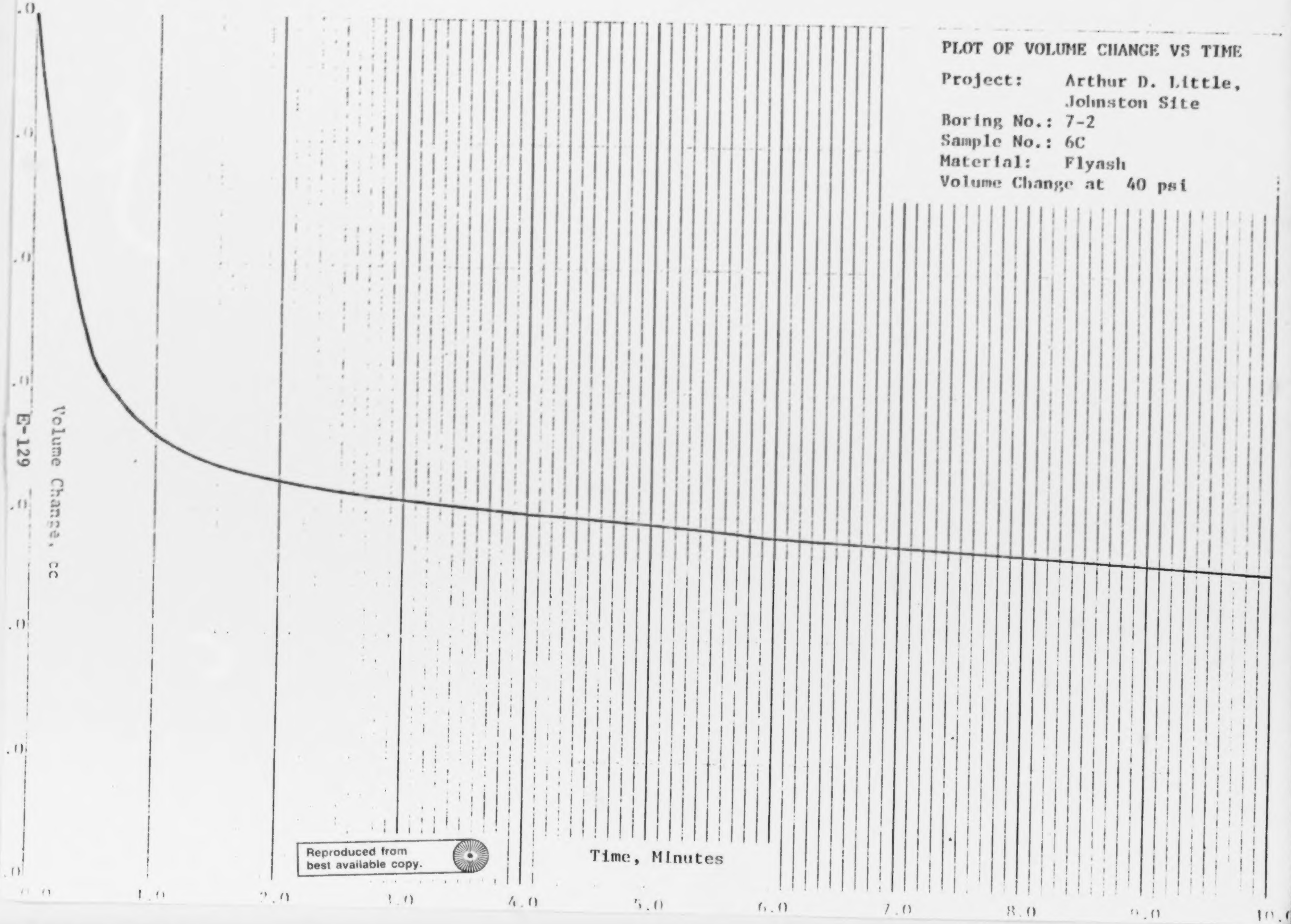


PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little,
Johnston Site
Boring No.: 7-2
Sample No.: 6C
Material: Flyash
Volume Change at 20 psi

10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0700



PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little,
Johnston Site
Boring No.: 7-2
Sample No.: 6C
Material: Flyash
Volume Change at 40 psi

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CONSTANT HEAD
PERMEABILITY TEST
LABORATORY COMPACTED

Project: Arthur D. Little, Johnston Site

Material Description: Gray Flyash, vicinity of boring 7-2

Method of Compaction: Static

SPECIMEN DATA

Compaction -

- Maximum Dry Unit Weight: 85.3 pcf
- Optimum Moisture Content: 16.5%
- Test Method: ASTM-D698-70, Method "C", 140°F

Dimensions -

- Height: 2.000"
- Diameter: 2.684"

Weight -

- Initial: 0.62 lbs.

Mositure Content -

- Initial: 13.9%
- Final: 28.0%

Wet Unit Weight -

- Initial: 94.7 pcf
- Final: 106.4 pcf

Dry Unit Weight -

- Initial: 83.1 pcf
- % Compaction: 97.4

Back Pressure Saturation -

- Pressures: 10 psi

Permeability -

- k: 4×10^{-5} cm/sec

CONSTANT HEAD
PERMEABILITY TEST
LABORATORY COMPACTED

Project: Arthur D. Little, Johnston Site

Material Description: Gray Flyash, vicinity of boring 7-2

Method of Compaction: Static

SPECIMEN DATA

Compaction -

Maximum Dry Unit Weight: 85.3 pcf
Optimum Moisture Content: 16.5%
Test Method: ASTM-D698-70, Method "C", 140°F

Dimensions -

Height: 1.974"
Diameter: 2.674"

Weight -

Initial: 0.55 lbs.

Mositure Content -

Initial: 15.2%
Final: 30.8%

Wet Unit Weight -

Initial: 85.7 pcf
Final: 97.3 pcf

Dry Unit Weight -

Initial: 74.4 pcf
% Compaction: 87.2

Back Pressure Saturation -

Pressures: 10 psi

Permeability -

k: 4×10^{-5} cm/sec

SPECIFIC GRAVITY

Project: Arthur D. Little, Johnston Site

Boring No.: 7-1

Sample No.: 1C

Depth: 4.5' - 6.5'

Procedure: ASTM-D854

TESTS RESULTS

Specific Gravity: 2.33

Material Description: Flyash

SPECIFIC GRAVITY

Project: Arthur D. Little, Johnston Site

Boring No.: 7-2

Sample No.: 1C

Depth: 4.5' - 6.5'

Procedure: ASTM-D854

TESTS RESULTS

Specific Gravity: 2.22

Material Description: Flyash

SPECIFIC GRAVITY

Project: Arthur D. Little, Johnston Site

Boring No.: 7-2

Sample No.: 6C

Depth: 29.0' - 31.0'

Procedure: ASTM-D854

TESTS RESULTS

Specific Gravity: 2.32

Material Description: Flyash

SPECIFIC GRAVITY

Project: Arthur D. Little, Johnston Site

Boring No.: 7-3A

Sample No.: 1C

Depth: 5.8' - 7.2'

Procedure: ASTM-D854

TESTS RESULTS

Specific Gravity: 2.29

Material Description: Flyash

SPECIFIC GRAVITY

Project: Arthur D. Little, Johnston Site

Boring No.: 7-3A

Sample No.: 2C

Depth: 13.0' - 15.0'

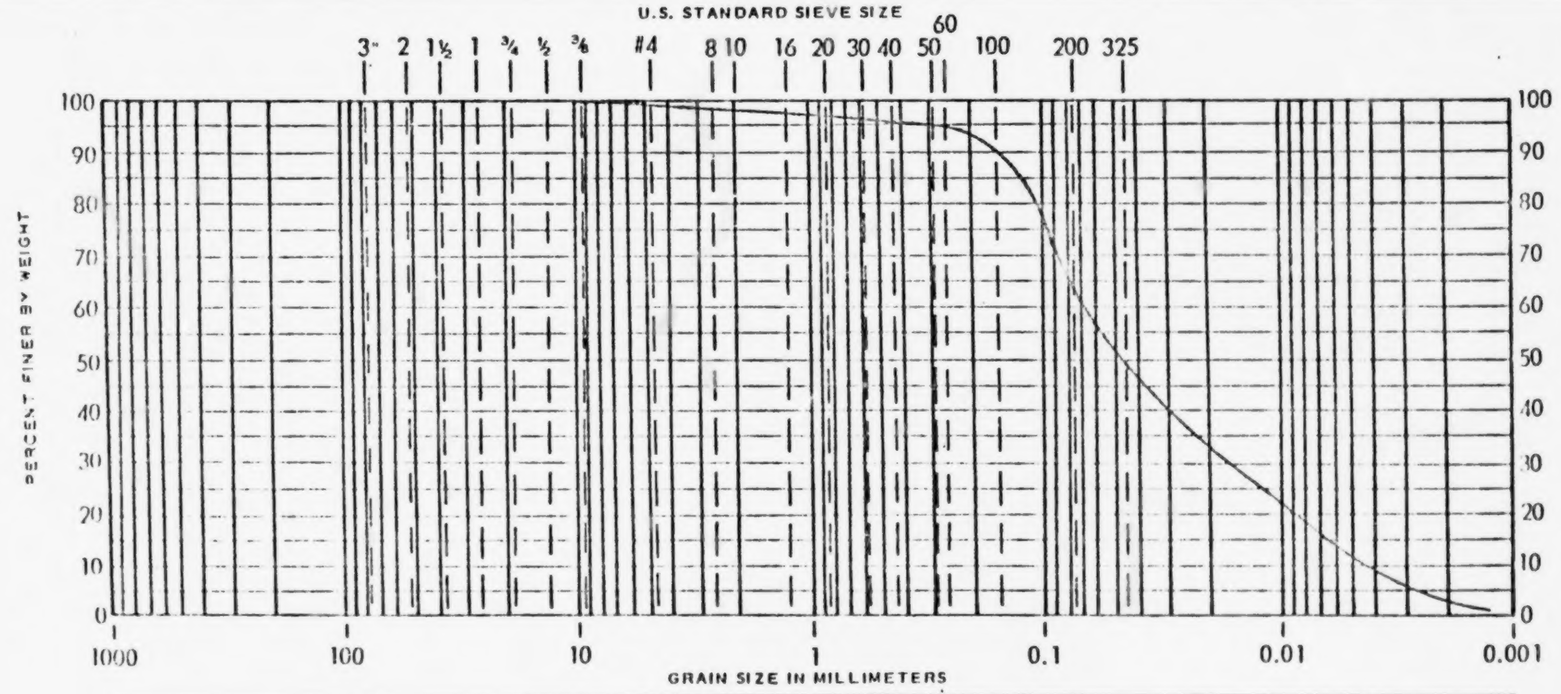
Procedure: ASTM-D854

TESTS RESULTS

Specific Gravity: 2.31

Material Description: Flyash

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 36%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	52%	11%

PROJECT Arthur D. Little,
Johnston Site
BORING NO. 7-1
SAMPLE NO. 4C
DEPTH 18.5-20.5'
CLASSIFICATION "ML"

sandy "SILT"

NATURAL % MOISTURE 10.9
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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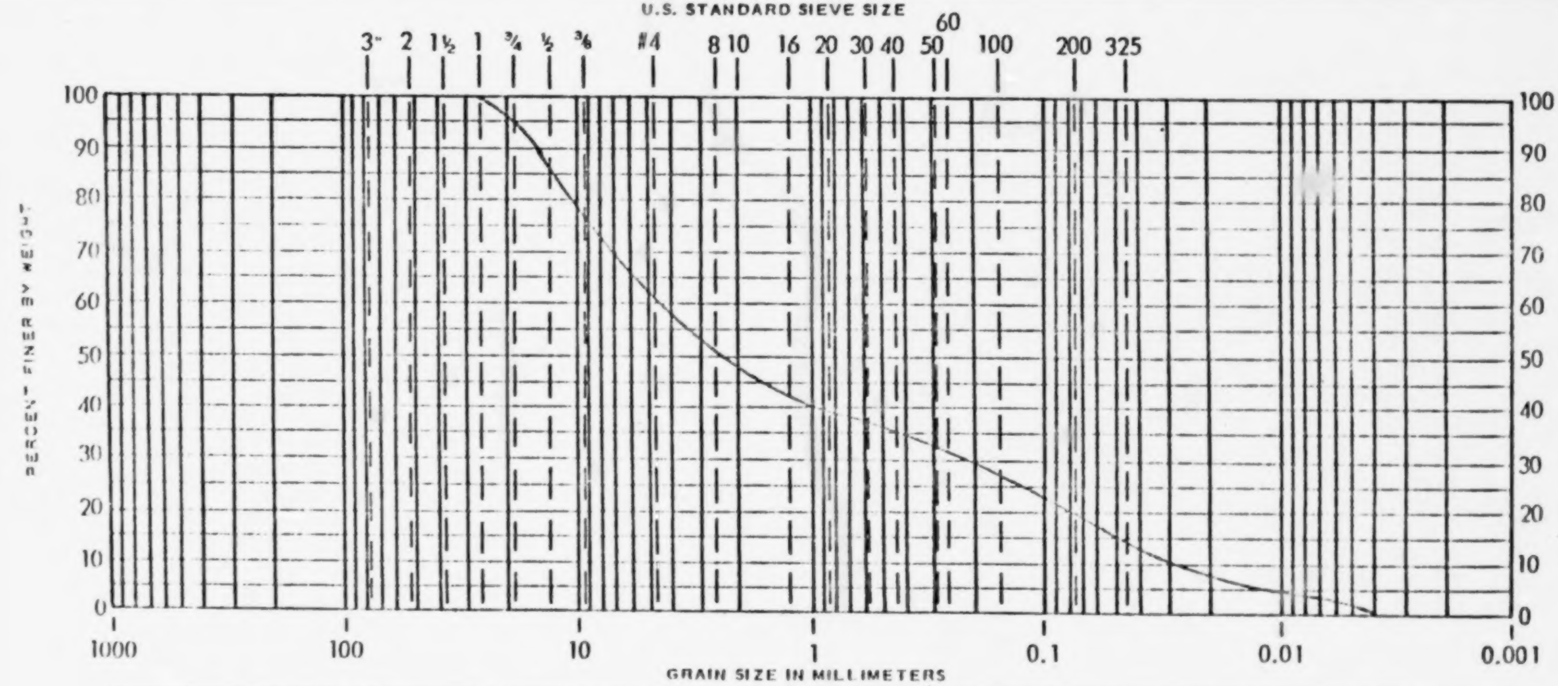

COBBLES	GRAVEL 38%		SAND 42%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	18%	2%

PROJECT Arthur D. Little,
Johnston Site
BORING NO. 7-1
SAMPLE NO. 1C
DEPTH 4.5-6.5'
CLASSIFICATION "SM"

gravelly, silty "SAND"

NATURAL % MOISTURE 11.2
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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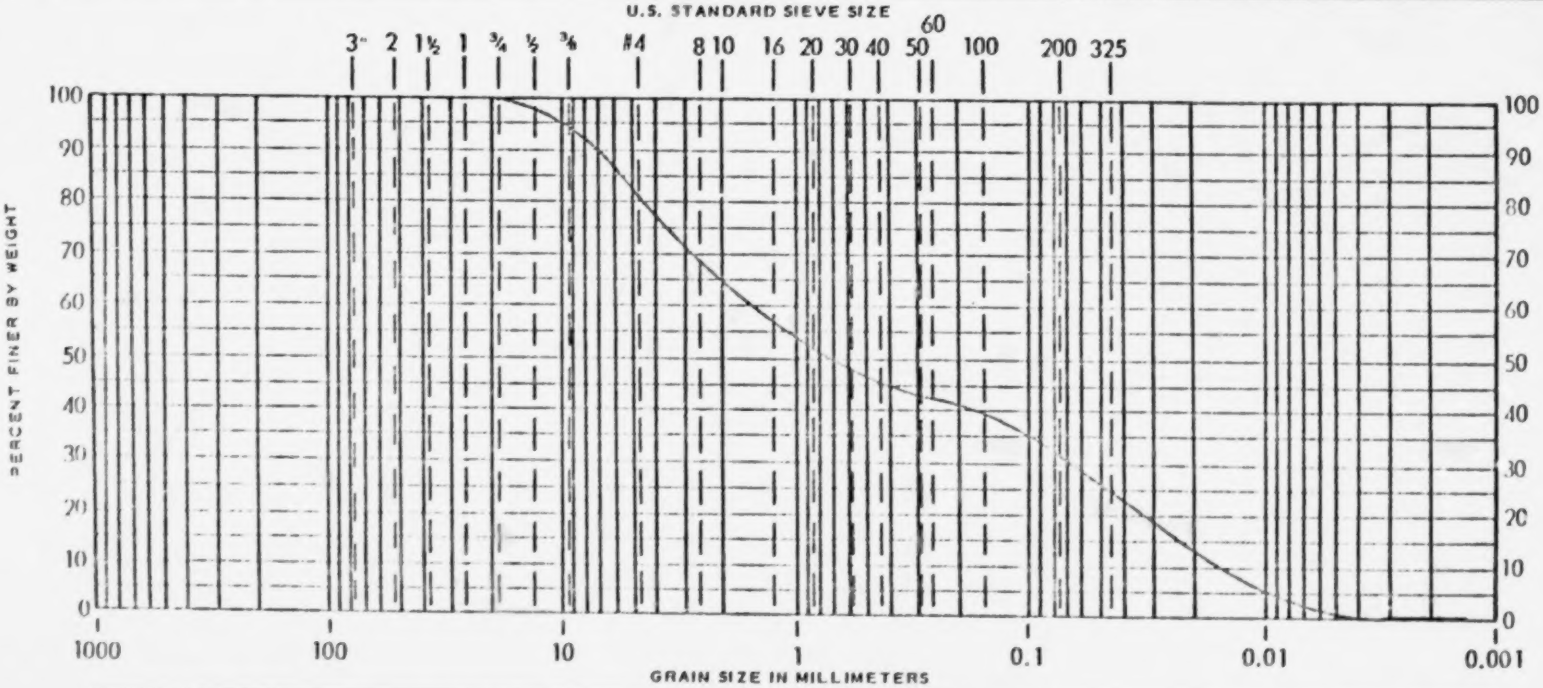

COBBLES	GRAVEL 2%		SAND 66%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	30%	2%

PROJECT Arthur D. Little,
Johnston Site
BORING NO. 7-2
SAMPLE NO. 1C
DEPTH 4.5-6.5'
CLASSIFICATION "SM"

silty "SAND"

NATURAL % MOISTURE 6.4
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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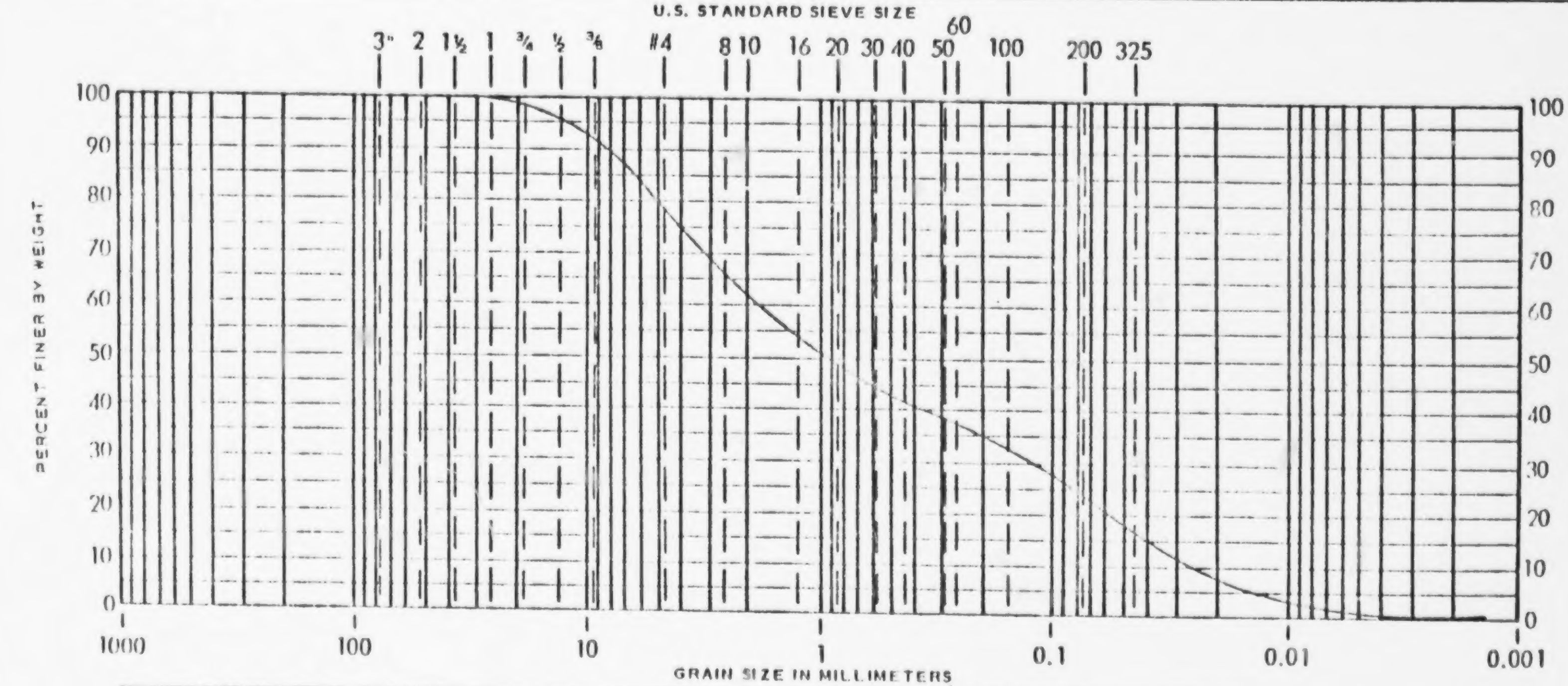

COBBLES	GRAVEL 22%		SAND 54%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	22%	2%

PROJECT Arthur D. Little,
Johnston Site
BORING NO. 7-2
SAMPLE NO. 3C
DEPTH 11.5-13.5'
CLASSIFICATION "SM"

gravelly, silty "SAND"

NATURAL % MOISTURE 5.4
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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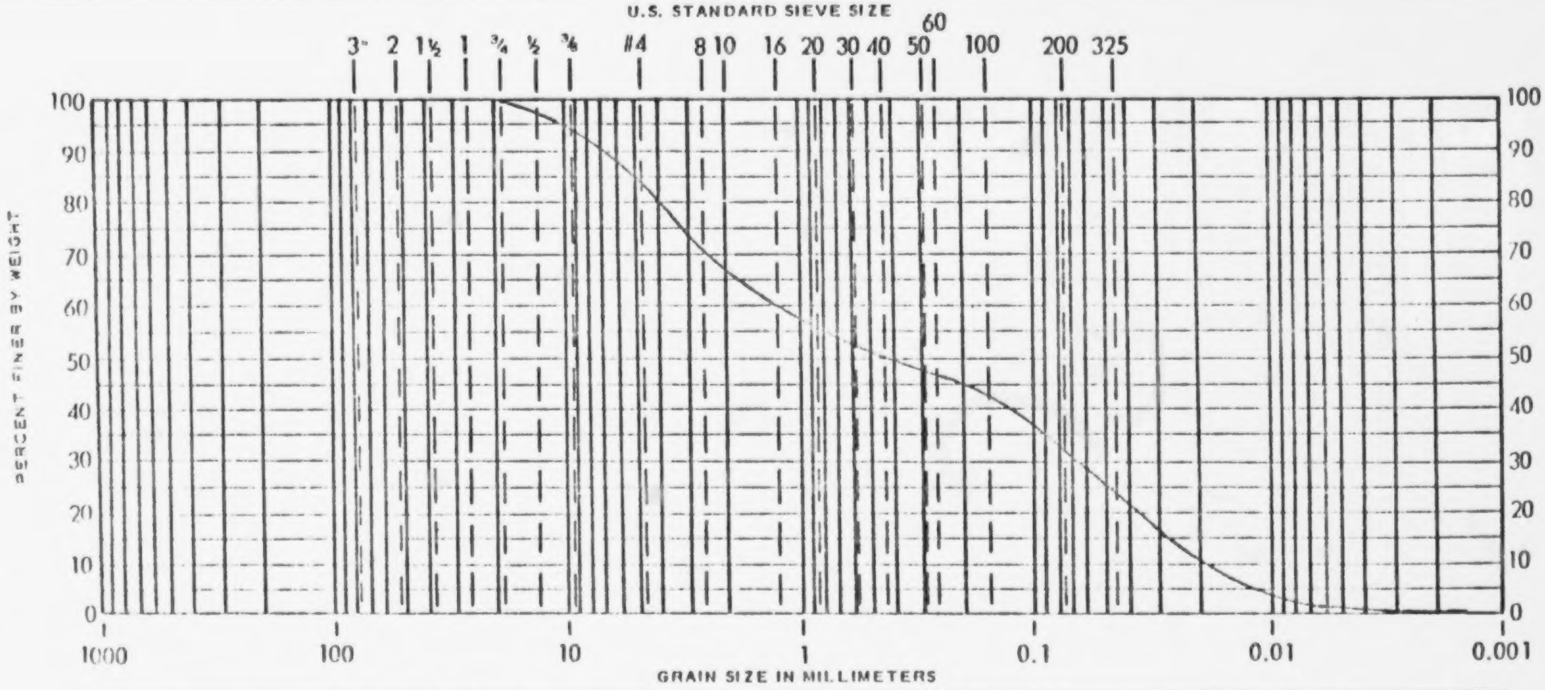

COBBLES	GRAVEL 17%		SAND 51%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	30%	2%

PROJECT Arthur D. Little,
Johnston Site
BORING NO. 7-2
SAMPLE NO. 6C
DEPTH 29.0-31.0'
CLASSIFICATION "SM"

gravelly, silty "SAND"

NATURAL % MOISTURE 2.3
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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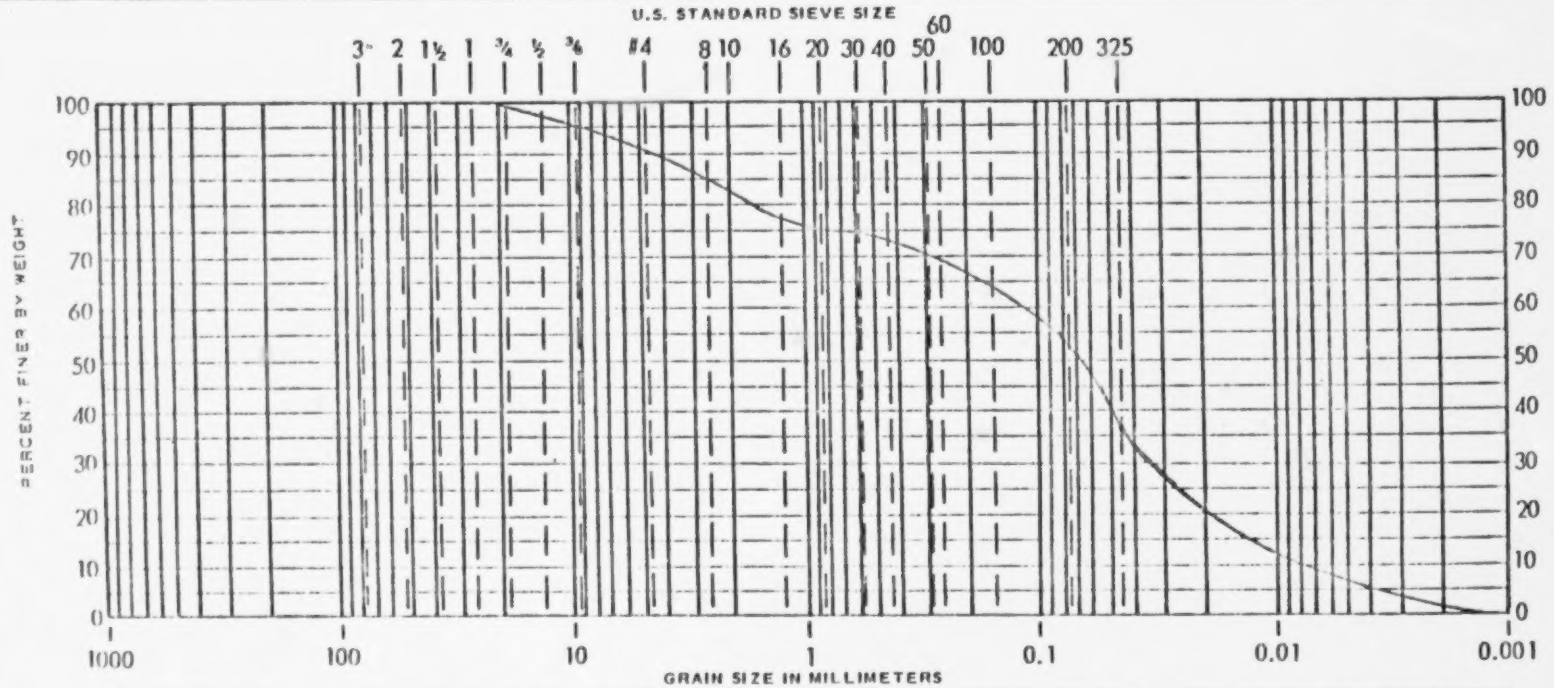

COBBLES	GRAVEL 9%		SAND 39%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	44%	8%

PROJECT Arthur D. Little,
Johnston Site
BORING NO. 7-3A
SAMPLE NO. 1C
DEPTH 5.8-7.2'
CLASSIFICATION "ML"

sandy "SILT"

NATURAL % MOISTURE 22.9
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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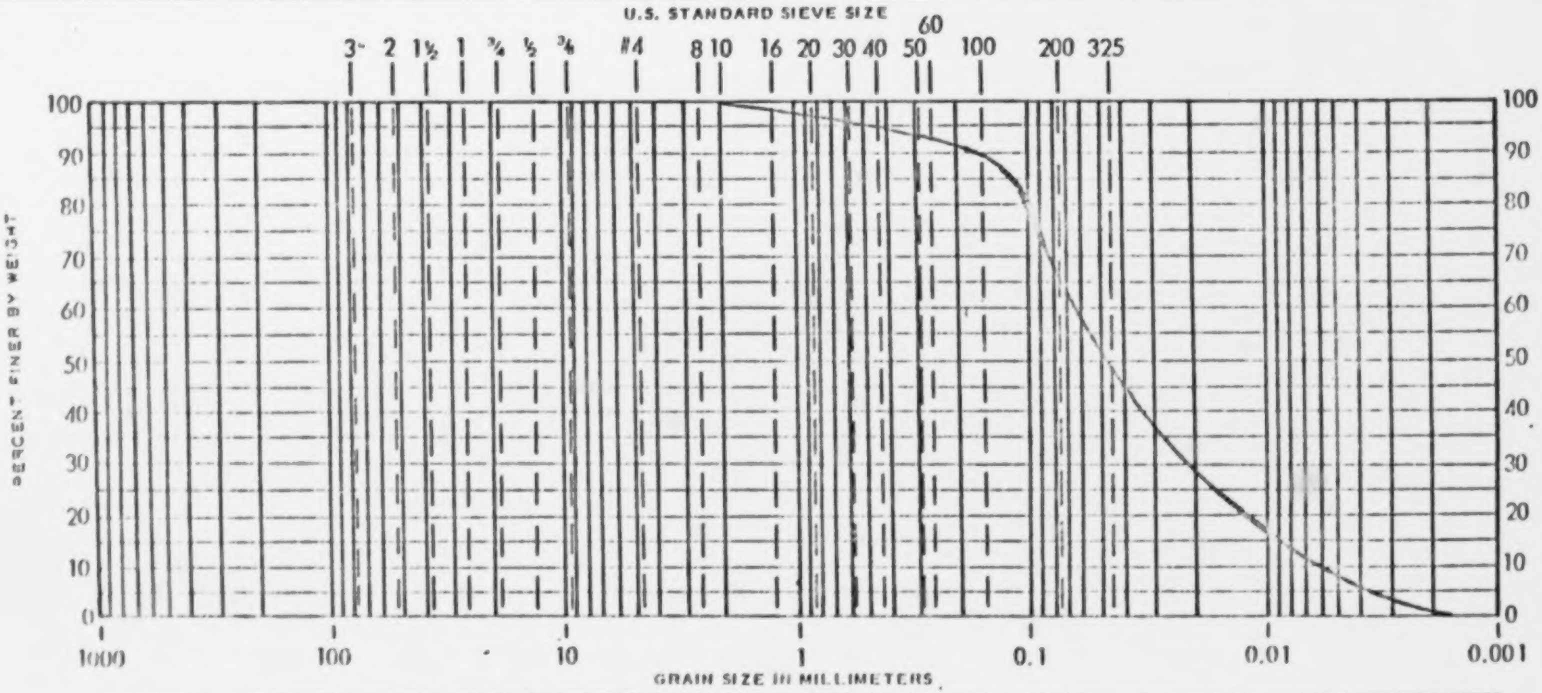

COBBLES	GRAVEL		SAND 32%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	62%	6%

PROJECT	Arthur D. Little, Johnston Site
BORING NO.	7-3A
SAMPLE NO.	2C
DEPTH	13.0-15.0'
CLASSIFICATION	"ML"

sandy "SILT"

NATURAL % MOISTURE	19.1
LIQUID LIMIT	Tested
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Gray
REMARKS	"U.S.C.S."

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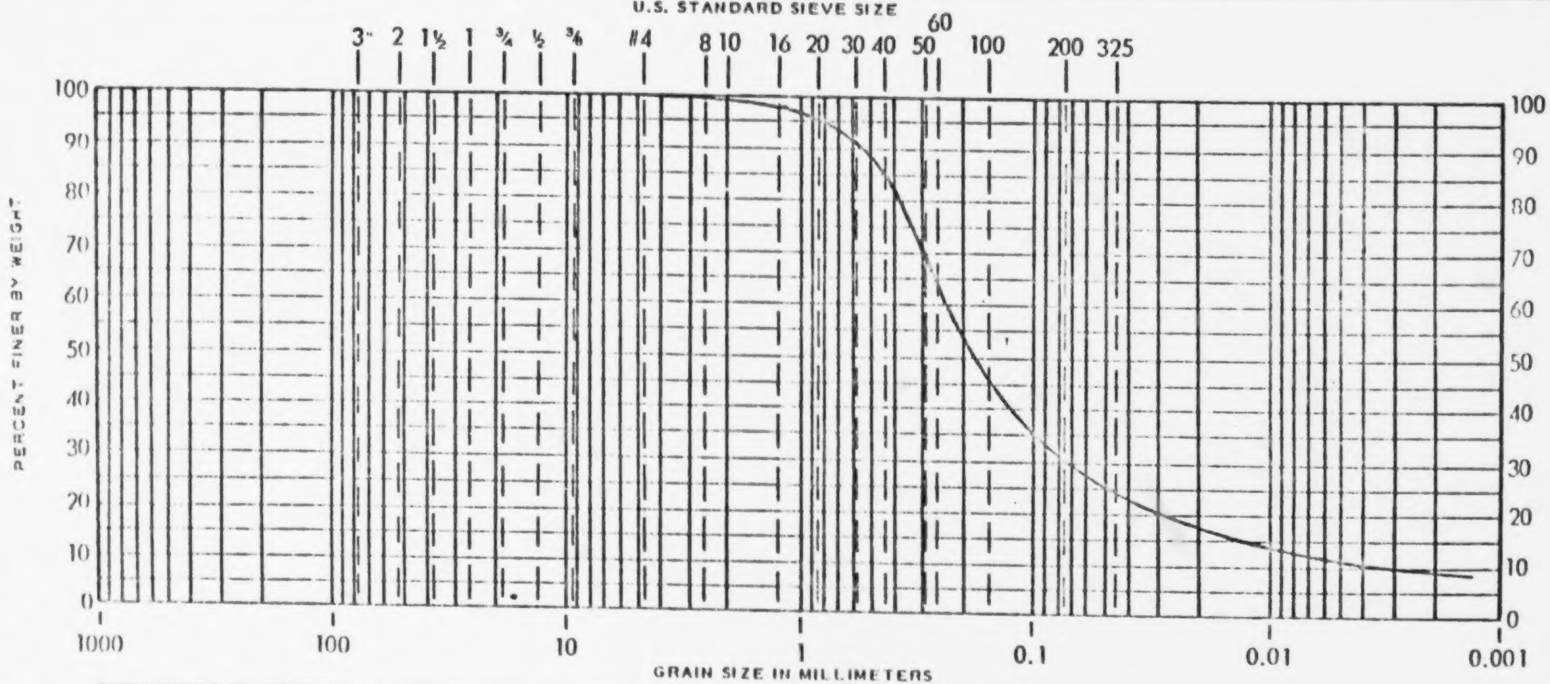

COBBLES	GRAVEL 0%		SAND 76%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	13%	11%

PROJECT Arthur D. Little,
Johnston Site
BORING NO. 7-4
SAMPLE NO. 6-S
DEPTH 10.0-11.5'
CLASSIFICATION "SM"

silty "SAND"

NATURAL % MOISTURE 25.2
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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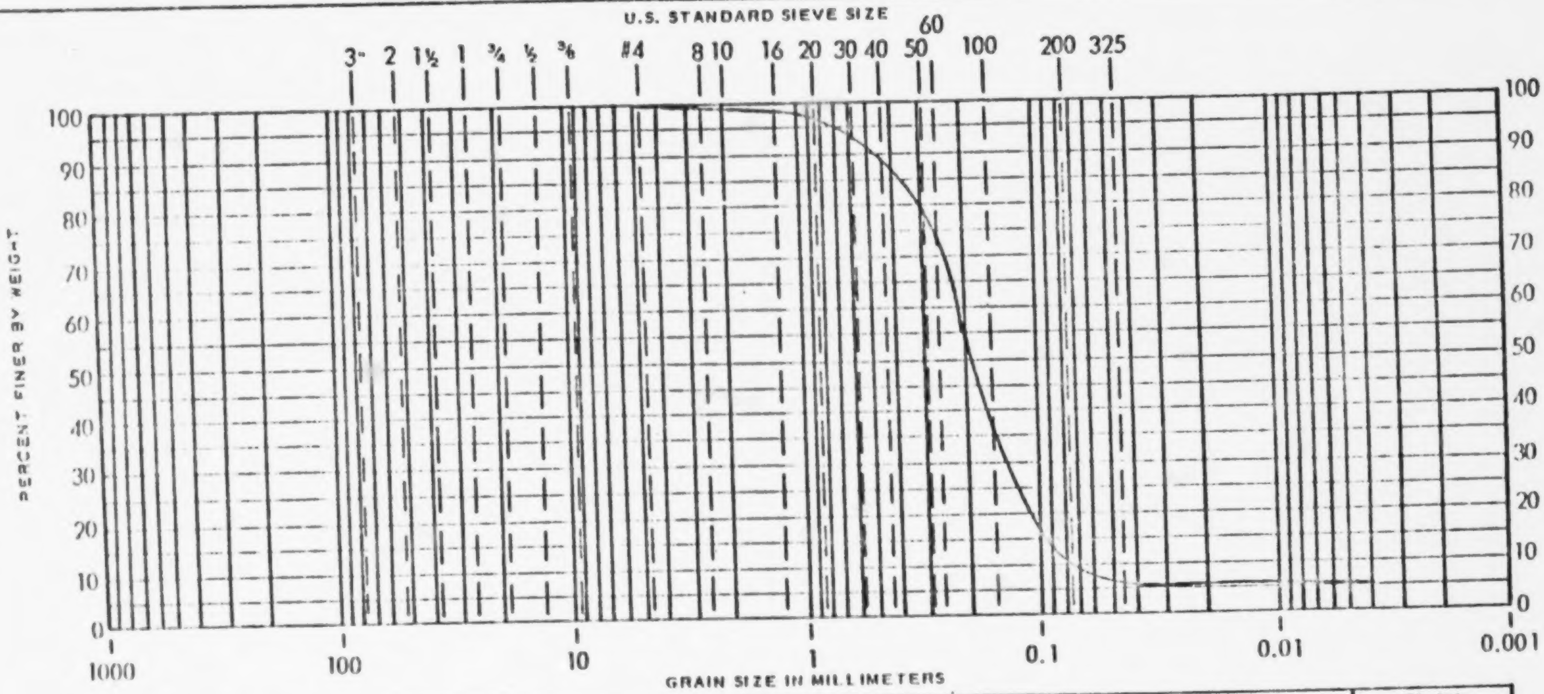

COBBLES	GRAVEL		SAND 93%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	2%	5%

PROJECT Arthur D. Little,
Johnston Site
BORING NO. 7-5
SAMPLE NO. 11S
DEPTH 20.0-22.0'
CLASSIFICATION "SP-SM"

poorly graded, silty "SAND"

NATURAL % MOISTURE 3.5
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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2A-34R

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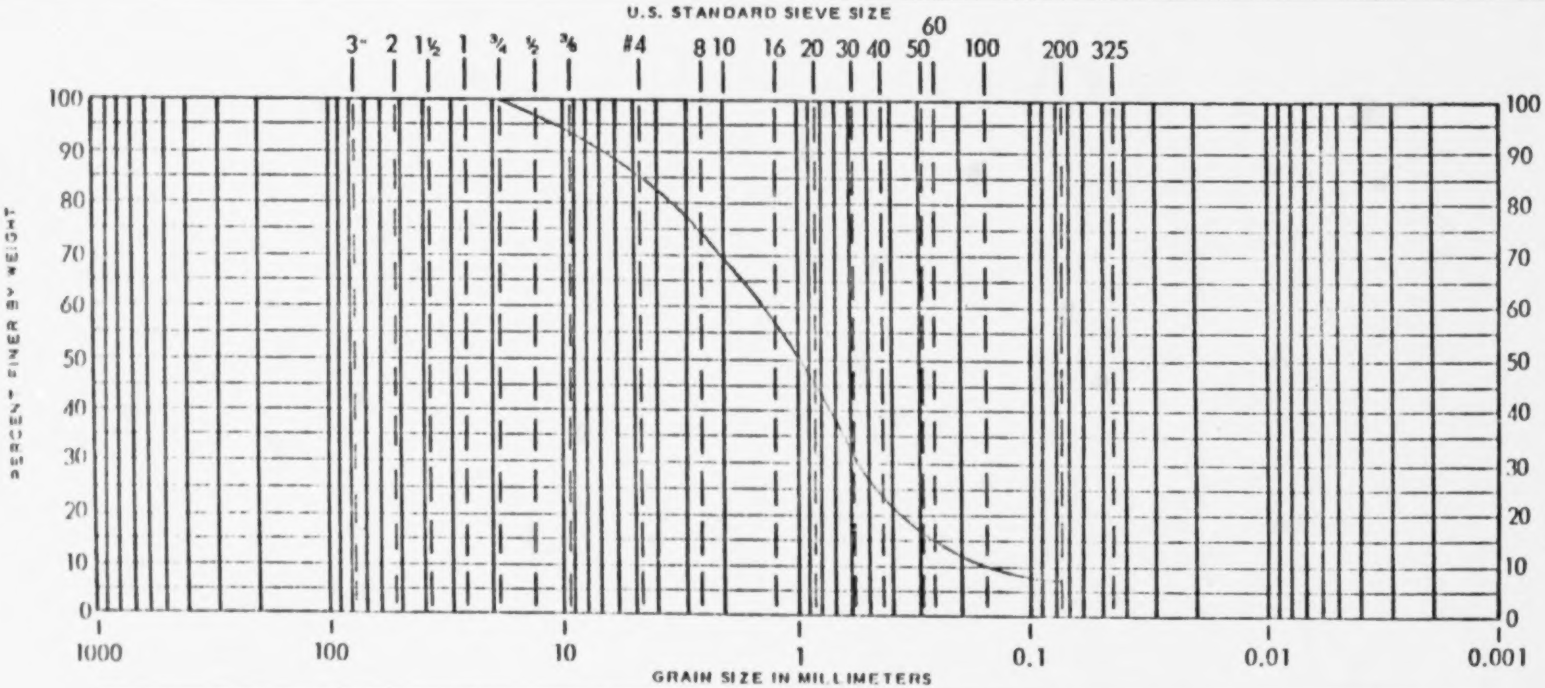

COBBLES	GRAVEL 12%		SAND 82%			SILT CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	- 6% -

PROJECT Arthur D. Little,
Johnston Site
BORING NO. 7-5
SAMPLE NO. 25S
DEPTH 56.5-58.0'
CLASSIFICATION "SW-SM"

gravelly, well graded silty
"SAND"

NATURAL % MOISTURE 8.6
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
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2A 348

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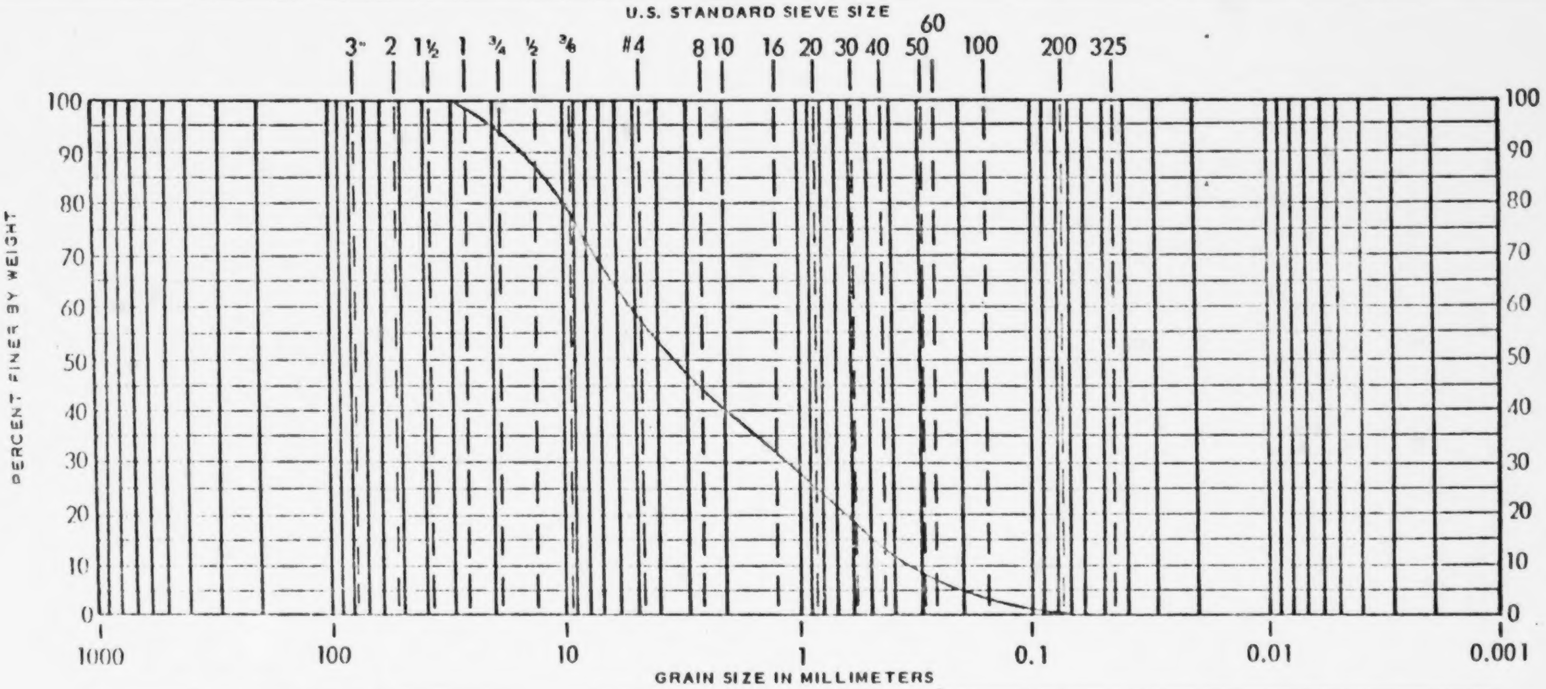

COBBLES	GRAVEL 44%		SAND 55%			SILT CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	- 1% -

PROJECT Arthur D. Little,
Johnston Site
BORING NO. 7-8
SAMPLE NO. S5
DEPTH 19.0-21.0'
CLASSIFICATION "SP"

Gravelly, poorly graded "SAND"

NATURAL % MOISTURE 7.0
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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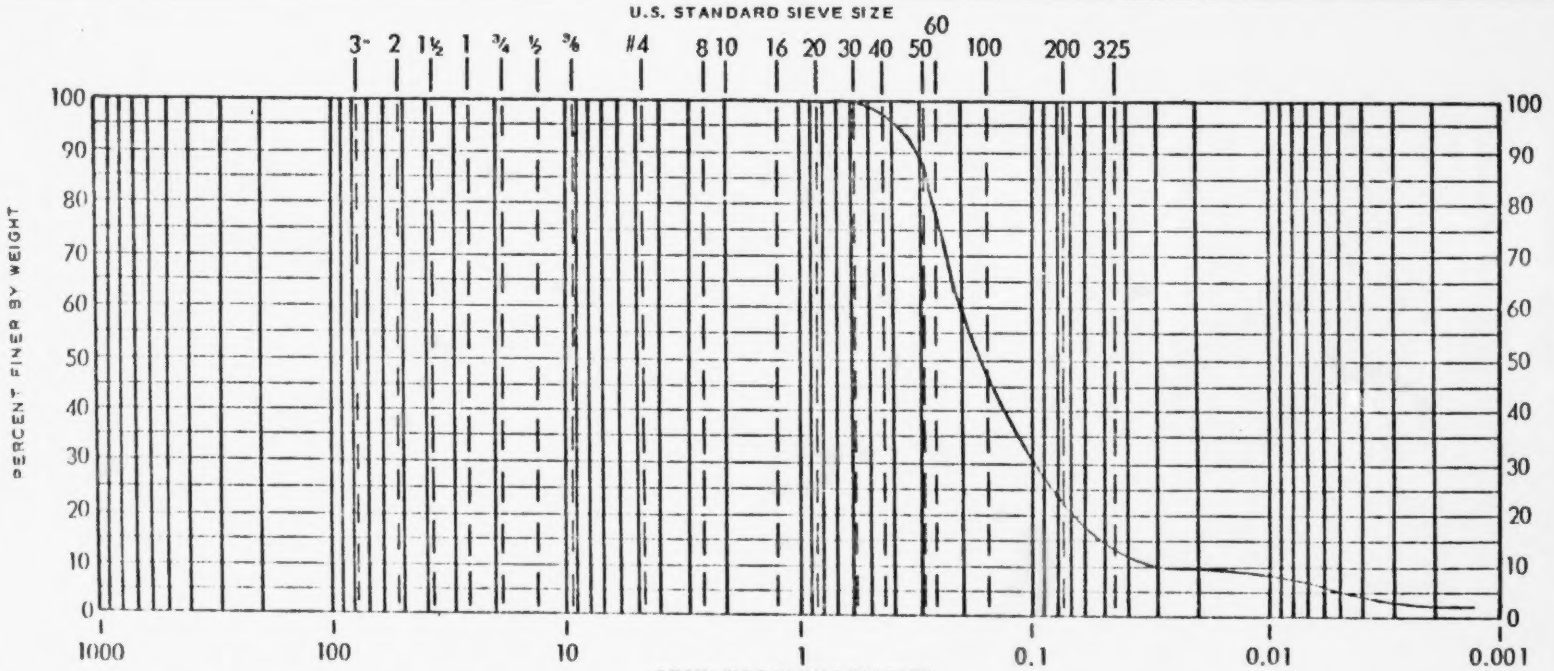

COBBLES	GRAVEL		SAND 78%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	17%	5%

PROJECT	Arthur D. Little, Johnston Site
BORING NO.	7-9
SAMPLE NO.	S8
DEPTH	19.0-20.0'
CLASSIFICATION	"SM"

silty "SAND"

NATURAL % MOISTURE	19.6
LIQUID LIMIT	Tested
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Gray
REMARKS	"U.S.C.S."

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LABORATORY SUMMARY SHEET

Arthur D. Little, Johnston Site

Page 1 of 4

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plas-ticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classi-fication
7-1	1S	0.0-2.0					21.1			
	2S	2.0-4.0					13.7			
	1C	4.5-6.5		Tested Non-Plastic			11.2			"SM"
	3S	6.5-8.5					9.2			
	2C	9.5-10.1					7.9			
	4S	10.1-12.1					4.1			
	3C	14.5-15.0					6.3			
	5S	15.0-15.5					5.9			
	4C	18.5-20.5	Permeability Tested Non-Plastic				10.9	66.4		"ML"
	6S	20.5-22.5					3.7			
	7S	26.5-28.5					2.0			
	8S	29.0-31.0					2.8			
	9S	34.0-36.0					6.5			
	10S	39.0-41.0					1.8			
	11S	44.0-46.0					0.7			
	12S	49.0-51.0					13.4			
	13S	54.0-56.0					6.4			
	14S	59.0-61.0					10.3			
7-1-A	1C	12.0-14.0	ON HOLD				----			
7-2	1S	0.0-2.0					18.9			
	2S	2.0-4.0					17.4			
	1C	4.5-6.5	Permeability Tested Non-Plastic				12.1	64.3		"SM"
	3S	6.5-8.5					5.5			
	3C	11.5-13.5	Permeability Tested Non-Plastic				5.4	73.5		"SM"
	4S	13.5-15.5					2.2			
	4C	19.0-21.0	ON HOLD				----			
	5S	21.0-23.0					3.0			
	5C	24.0-26.0	ON HOLD				----			
	6S	26.0-28.0					2.9			

LABORATORY SUMMARY SHEET

Arthur D. Little, Johnston Site

Page 2 of 4

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
	6C	29.0-31.0	Permeability	Tested Non-Plastic			2.3	69.0		"SM"
	7S	31.0-33.0					3.3			
	7C	34.0-36.0	ON HOLD				----			
	8S	36.0-38.0					2.2			
	9S	39.0-41.0					12.8			
	10S	43.0-45.0					21.1			
	11S	45.0-47.0					31.9			
	12S	49.0-50.5					5.4			
	13S	54.0-56.0					5.8			
	14S	59.0-60.0					14.0			
7-3	1S	0.0-2.0					7.8			
	2S	2.5-4.5					9.4			
	3S	4.5-6.5					12.5			
	4S	7.5-9.5					18.3			
	5S	9.5-11.5					15.3			
	6S	12.0-14.0					3.2			
	8S	18.5-20.5					3.5			
	9S	21.0-23.0					2.5			
	10S	23.5-25.5					1.2			
	11S	26.0-28.0					14.7			
	12S	28.5-30.5					15.4			
	13S	34.0-34.5					19.9			
	14S	39.0-39.5					18.6			
	15S	44.0-44.5					20.9			
	16S	49.0-49.5					25.4			
	18S	54.5-55.0					23.7			
	19S	59.0-60.5					17.0			
7-3-A	1C	5.8-7.2	Permeability	Tested Non-Plastic			22.9	65.5		"ML"
	2C	13.0-15.0		Tested Non-Plastic			19.1			"ML"

LABORATORY SUMMARY SHEET

Arthur D. Little, Johnston Site

Page 3 of 4

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
7-4	6S	10.0-11.5			Tested Non-Plastic		17.8			"SM"
7-4-A	1S	19.0-20.0					17.6			
	2S	24.0-25.0					20.1			
	3S	29.0-30.5					13.9			
	4S	34.0-35.0					10.8			
	5S	39.0-40.0					13.0			
7-5	1S	0.0-2.0					3.5			
	2S	2.0-4.0					15.2			
	3S	4.0-6.0					0.4			
	4S	6.0-8.0					2.7			
	5S	8.0-10.0					3.4			
	6S	10.0-12.0					1.5			
	7S	12.0-14.0					2.2			
	8S	14.0-16.0					2.7			
	9S	16.0-18.0					1.2			
	10S	18.0-20.0					1.9			
	11S	20.0-22.0			Visually Non-Plastic		3.5			"SP-SM"
	12S	22.0-24.0					5.6			
	13S	24.0-26.0					2.8			
	14S	26.0-28.0					1.2			
	15S	28.0-30.0					2.6			
	16S	30.0-32.0					1.2			
	17S	32.0-34.0					3.0			
	18S	34.0-36.0					1.5			
	19S	36.0-38.0					1.6			
	20S	38.0-40.0					1.3			
	21S	40.0-42.0					1.8			
	22S	42.0-44.0					1.0			
	23S	49.0-51.0					1.3			
	24S	54.0-56.0								
	25S	56.0-58.0			Visually Non-Plastic		8.6			"SW-SM"

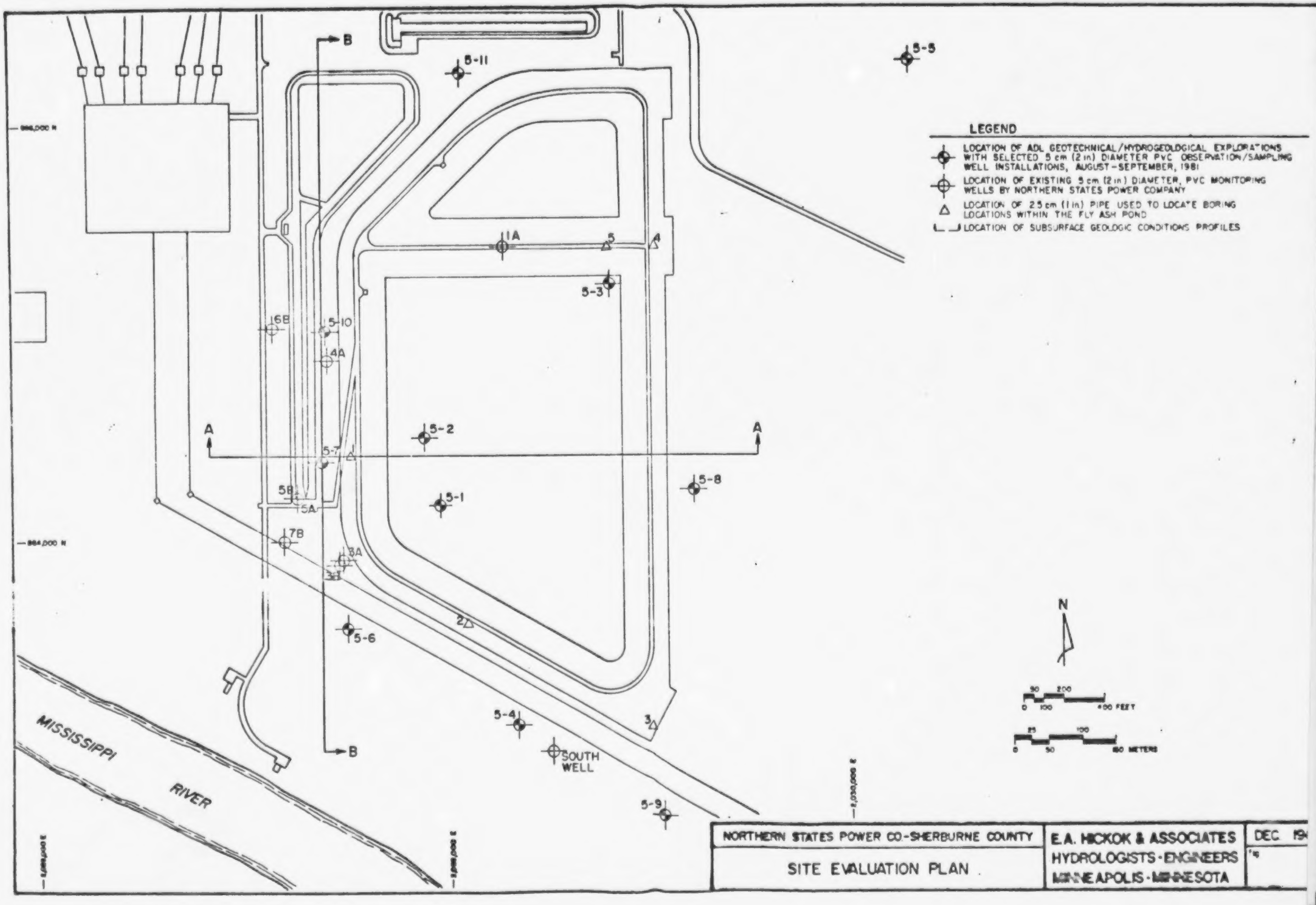
LABORATORY SUMMARY SHEET

Arthur D. Little, Johnston Site

Page 4 of 4

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plas-ticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classi-fication
7-6	5S	8.0-10.0					9.9			
	6S	10.0-12.0					16.4			
	9S	16.0-18.0					4.2			
	10S	18.0-20.0					5.1			
	12S	29.0-30.0					12.0			
	13S	34.0-35.0					15.9			
	14S	39.0-40.0					16.9			
7-7	1S	0.0-2.0					4.9			
	3S	9.0-11.0					1.2			
	4S	14.0-16.0					1.7			
	5S	19.0-21.0					1.6			
	7S	29.0-30.0					7.7			
	8S	34.0-34.5					12.8			
	9S	39.0-39.5					9.1			
	10S	44.0-44.5					12.4			
7-8	1S	0.0-2.0					3.5			
	2S	4.0-6.0					4.8			
	5S	19.0-21.0			Visually Non-Plastic		7.0			"SP"
	6S	24.0-24.5					26.4			
	7S	29.0-30.0					14.2			
7-9	5S	8.0-10.0					15.3			
	8S	19.0-20.0			Tested Non-Plastic		19.6			"SM"
	9S	24.0-25.0					15.1			
	10S	29.0-30.0					14.2			
	11S	34.0-35.0					14.5			
	12S	39.0-40.0					12.4			
	13S	42.0-42.5					6.7			

Sherco Northern States Power



LEGEND
LOCATION OF ADL GEOTECHNICAL/HYDROGEOLOGICAL EXPLORATIONS WITH SELECTED 5 cm (2 in) DIAMETER PVC OBSERVATION/SAMPLING WELL INSTALLATIONS, AUGUST-SEPTEMBER, 1981
LOCATION OF EXISTING 5 cm (2 in) DIAMETER, PVC MONITORING WELLS BY NORTHERN STATES POWER COMPANY
△ LOCATION OF 2.5 cm (1 in) PIPE USED TO LOCATE BORING LOCATIONS WITHIN THE FLY ASH POND
LOCATION OF SUBSURFACE GEOLOGIC CONDITIONS PROFILES
5-11
5-5
B
B
A
A
1A
5
4
5-3
16B
5-10
4A
5-2
5-7
5B
5A
5-1
5-8
7B
3A
3
2
5-6
3
5-4
SOUTH WELL
5-9
MISSISSIPPI RIVER
N
0 50 100 200 400 FEET
0 25 50 100 150 METERS
986,000 N
984,000 N
2,030,000 E

NORTHERN STATES POWER CO-SHERBURNE COUNTY

SITE EVALUATION PLAN

E.A. HICKOK & ASSOCIATES
HYDROLOGISTS-ENGINEERS
MINNEAPOLIS-MINNESOTA

DEC 19

UNIVERSITY OF LOUISVILLE
LOUISVILLE, KENTUCKY ~~40208~~ 40292

SPEED SCIENTIFIC SCHOOL
JAMES BRECKENRIDGE SPEED FOUNDATION
DEPARTMENT OF CIVIL ENGINEERING

November 12, 1981

MEMO TO: C. J. Santhanam, ADL

FROM. .: C. R. Ullrich, UL CR Ullrich

SUBJECT: QA/QC Physical Property Tests

Please find attached a summary of results of QA/QC physical property tests performed by University of Louisville personnel on waste samples obtained from the Sherco site. Samples consisted of soft sludge materials contained in Ball jars and 2-inch-diameter Shelby tubes. Test results are reported for permeability tests done on remolded, compacted samples of materials contained in the Ball jars; also, test results are reported for unconfined compression tests done on undisturbed materials contained in Shelby tubes, and permeability tests done on remolded, compacted materials from Shelby tubes (depth intervals are noted).

Thus far, QA/QC work has been completed on El Rama, Allen, and Sherco materials. QA/QC samples from Dave Johnson have not been received.

tgc

EXHIBIT 4.4.2

SUMMARY OF RESULTS

QA/QC PHYSICAL PROPERTY TESTS

SHERCO SITE

I. Shelby Tube Samples

Boring No. 5-2
Sample No. U2
Depth 18.5' - 20.5'
Date of Sampling: August 23, 1981

A. Results of permeability tests on remolded, compacted samples:

Depth Interval (ft.)	Material	Water Content (%)	Moist Density (pcf)	Dry Density (pcf)	Coefficient of Permeability (cm/sec)
19.5-20.0	sludge	43.2	104.8	73.0	9.22×10^{-4}
20.0-20.5	sludge	45.4	102.3	70.5	2.29×10^{-4}

B. Results of unconfined compression tests on undisturbed samples:

Depth Interval (ft)	Material	Water Content (%)	Unconfined Compressive Strength (psf)
19.5-20.0	sludge	40.9	252
20.0-20.5	sludge	45.4	706

II. Ball Jar Samples

Boring No. 5-3
Sample No. U2
Depth 10' - 12'
Date of sampling: August 25, 1981

A. Results of permeability tests on remolded, compacted samples:

Depth Interval (ft.)	Material	Water Content (%)	Moist Density (pcf)	Dry Density (pcf)	Coefficient of Permeability (cm/sec)
10.0-12.0	sludge	34.9	106.7	79.2	4.18×10^{-4}

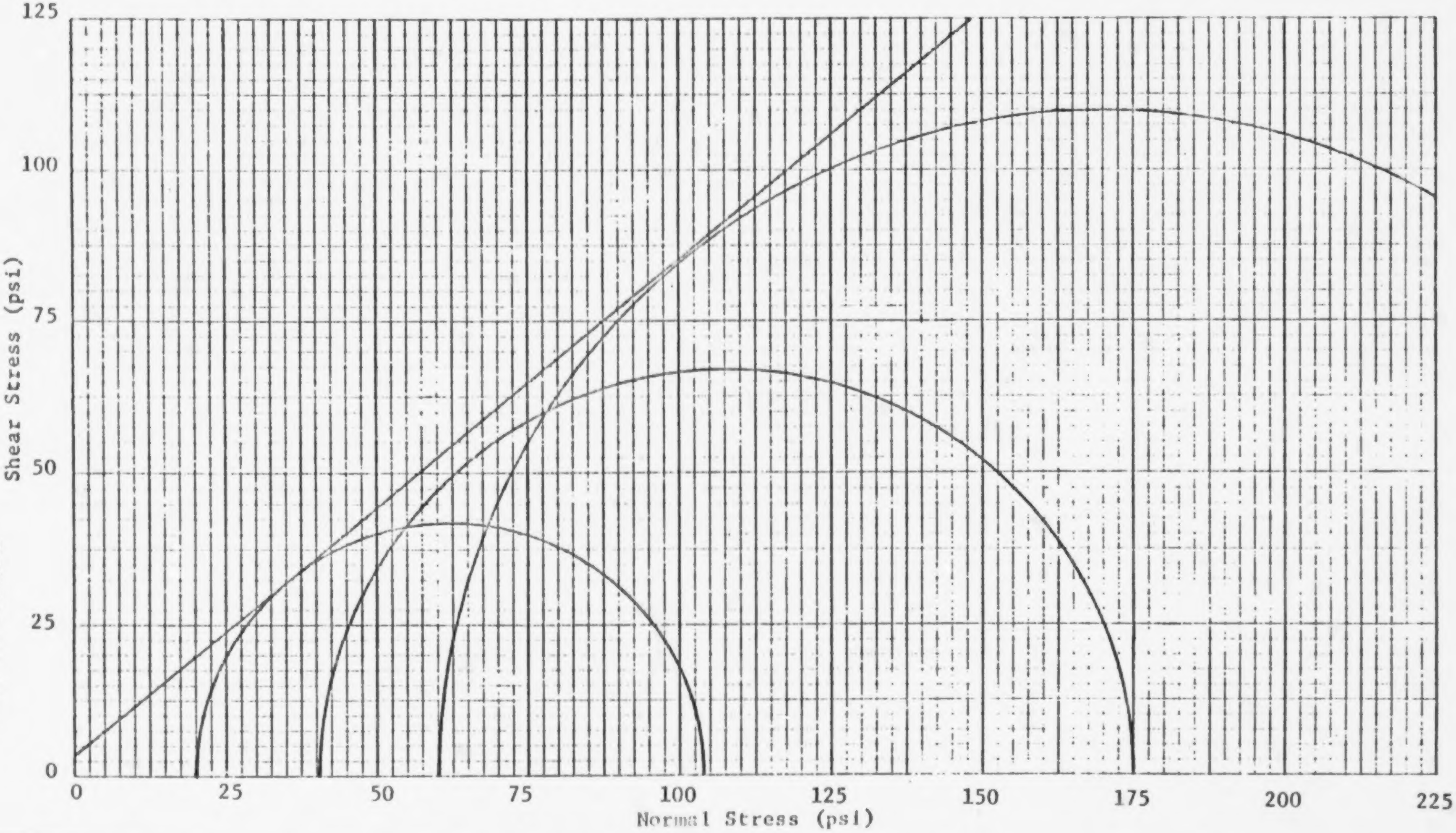
SHERCO

UNCONSOLIDATED-UNDRAINED TRIAXIAL TEST
MOHR PLOTS OF FAILURE STATES

Project: Arthur D. Little, Sherco Site
Material: Undisturbed FGD Sludge
Source of Material: Boring B5-2, Sample U1A, and Boring B5-2A, Sample U1

Strength Parameters:	C (psi)	ϕ(°)
Total	5.7	58.4

——— = Total



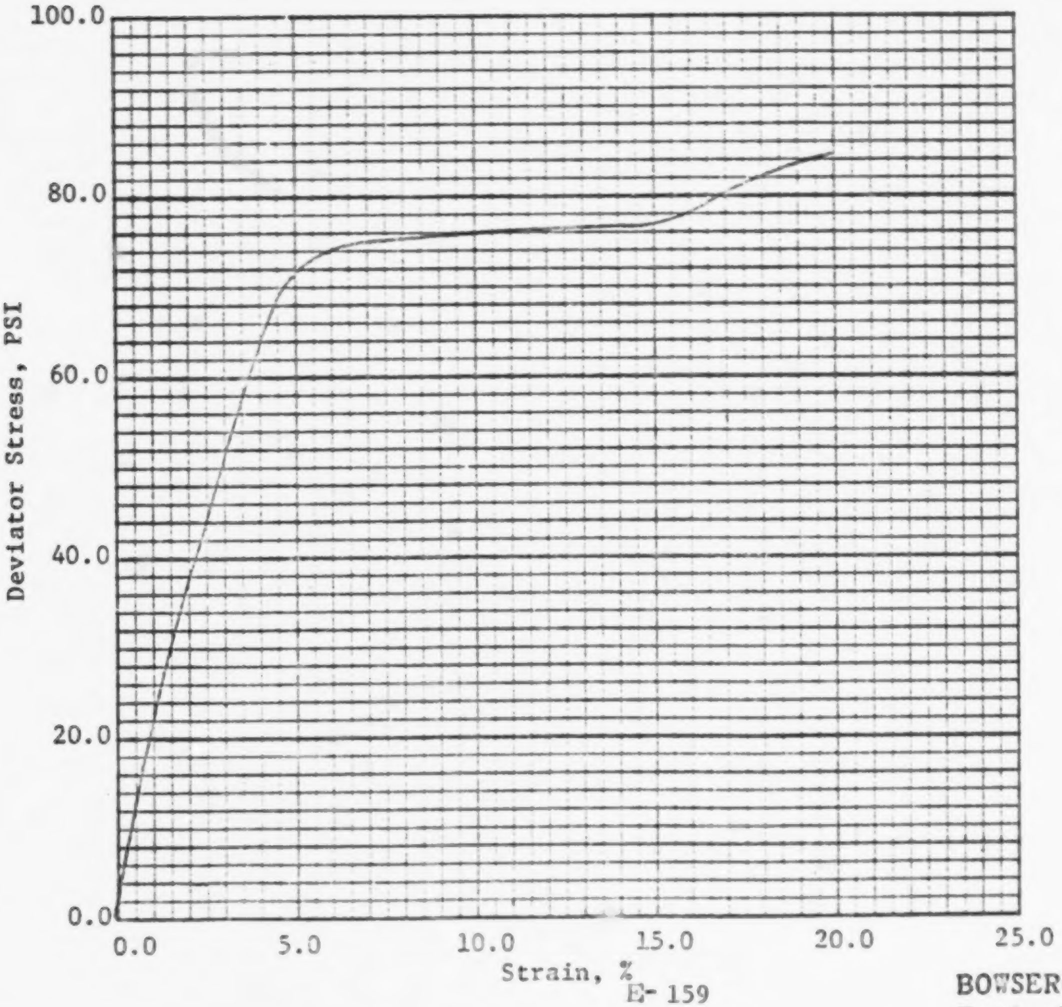
BOWSER-MORNER
Testing Laboratories, Inc.

Project:	Arthur D. Little, Sherco Site
Boring No.:	5-2A
Sample No.:	U1
Depth Interval of Sample:	6.5-8.5'
Depth Interval of Test Sample:	7.5-8.0'
Test Method:	ASTM-D-2850-70

SPECIMEN DATA:

Undisturbed:

Initial Diameter:	2.877"
Initial Height:	5.982"
Test Specimen Weight:	2.33 lbs.
Moisture Content:	27.7 %
Wet Unit Weight:	103.5 pcf
Dry Unit Weight:	81.0 pcf
Stress at Failure:	84.2 psi
Strain at Failure:	20.0 %
Height at Failure:	4.786"
Lateral Pressure:	20.0 psi
Soil Classification	FGD Sludge



BOWSER-MORNER
Testing Laboratories, Inc.

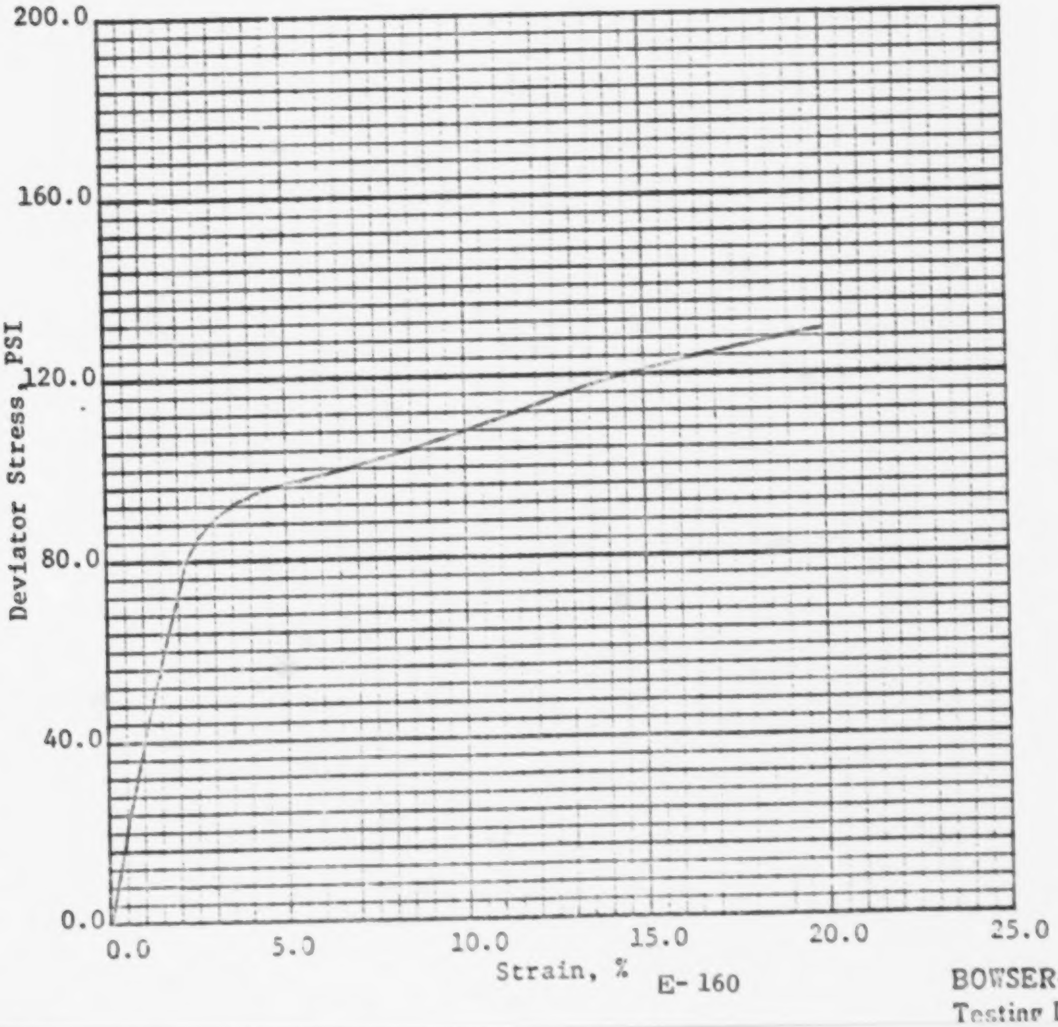
Unconsolidated-Undrained Triaxial Test

Project:	Arthur D. Little, Sherco Site
Boring No.:	B-5-2
Sample No.:	U1A
Depth Interval of Sample:	6.5-8.5'
Depth Interval of Test Sample:	7.1-7.6'
Test Method:	ASTM-D-2850-70

SPECIMEN DATA

Undisturbed

Initial Diameter:	2.888"
Initial Height:	5.938"
Test Specimen Weight:	2.21 lbs.
Moisture Content:	29.3 %
Wet Unit Weight:	98.2 pcf
Dry Unit Weight:	75.9 pcf
Stress at Failure:	129.0 psi
Strain at Failure:	20.0 %
Height at Failure:	4.750"
Lateral Pressure:	40.0 psi
Soil Classification:	FGD Sludge

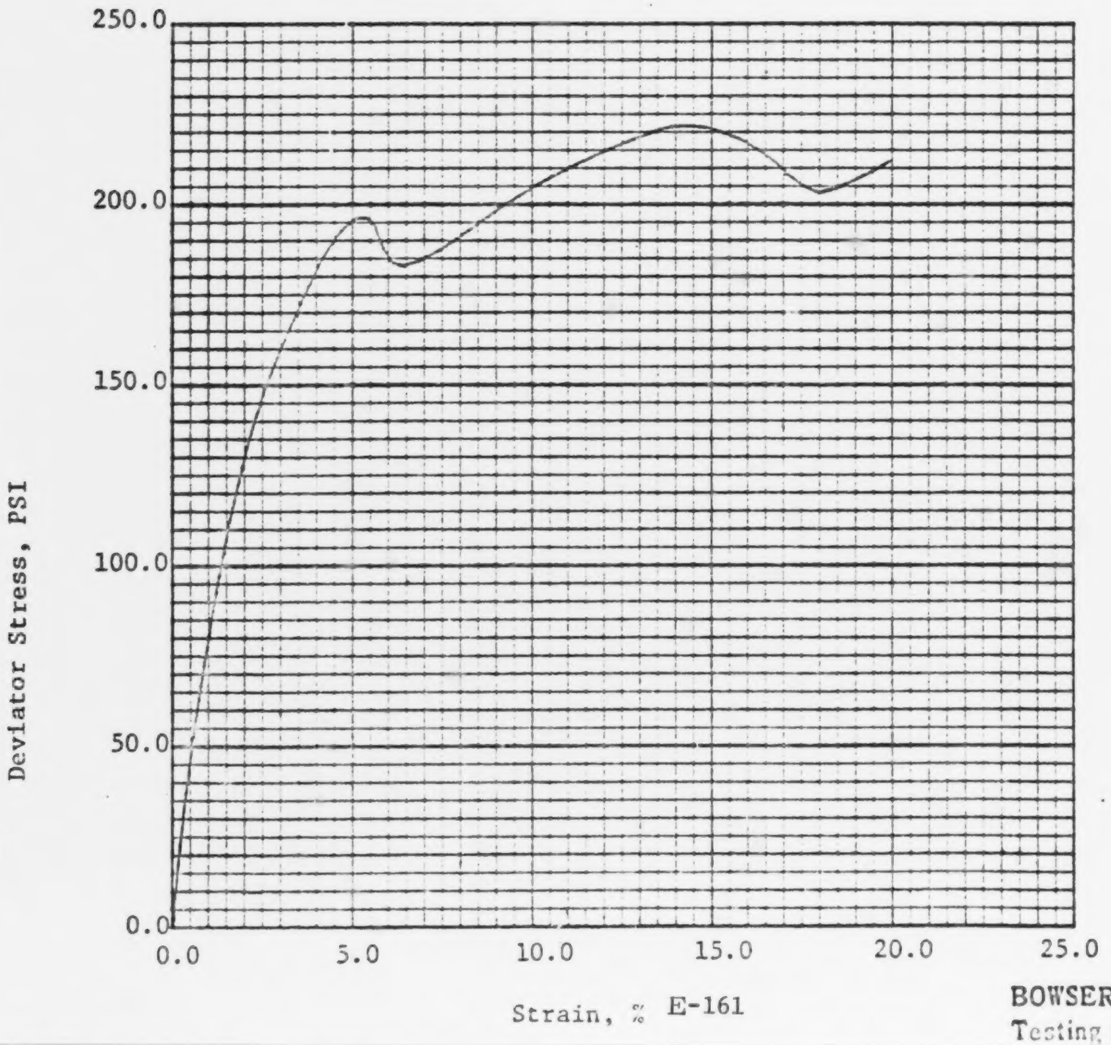


Unconsolidated-Undrained Triaxial Test

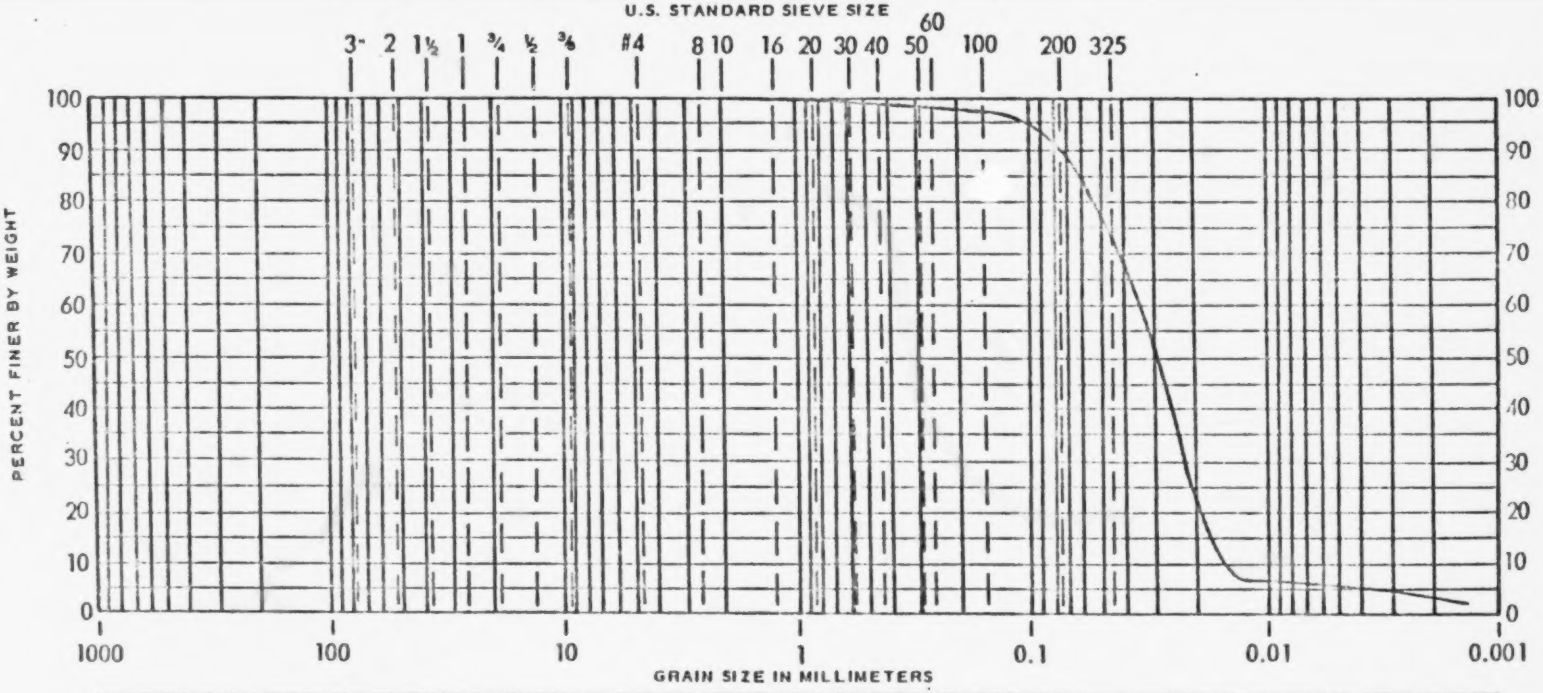
Project: Arthur D. Little, Sherco Site
Boring No.: 5-2A
Sample No.: U1
Depth Interval of Sample: 6.5-8.5'
Depth Interval of Test Sample: 8.0-8.5'
Test Method: ASTM-D-2850-70

SPECIMEN DATA

Undisturbed:
Initial Diameter: 2.883"
Initial Height: 5.770"
Test Specimen Weight: 2.47 lbs.
Moisture Content: 27.7 %
Wet Unit Weight: 109.6 pcf
Dry Unit Weight: 85.8 pcf
Stress at Failure: 221.0 psi
Strain at Failure: 14.7 %
Height at Failure: 5.092"
Lateral Pressure: 60.0 psi
Soil Classification: FGD Sludge



SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 0%		SAND 8%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	86%	6%

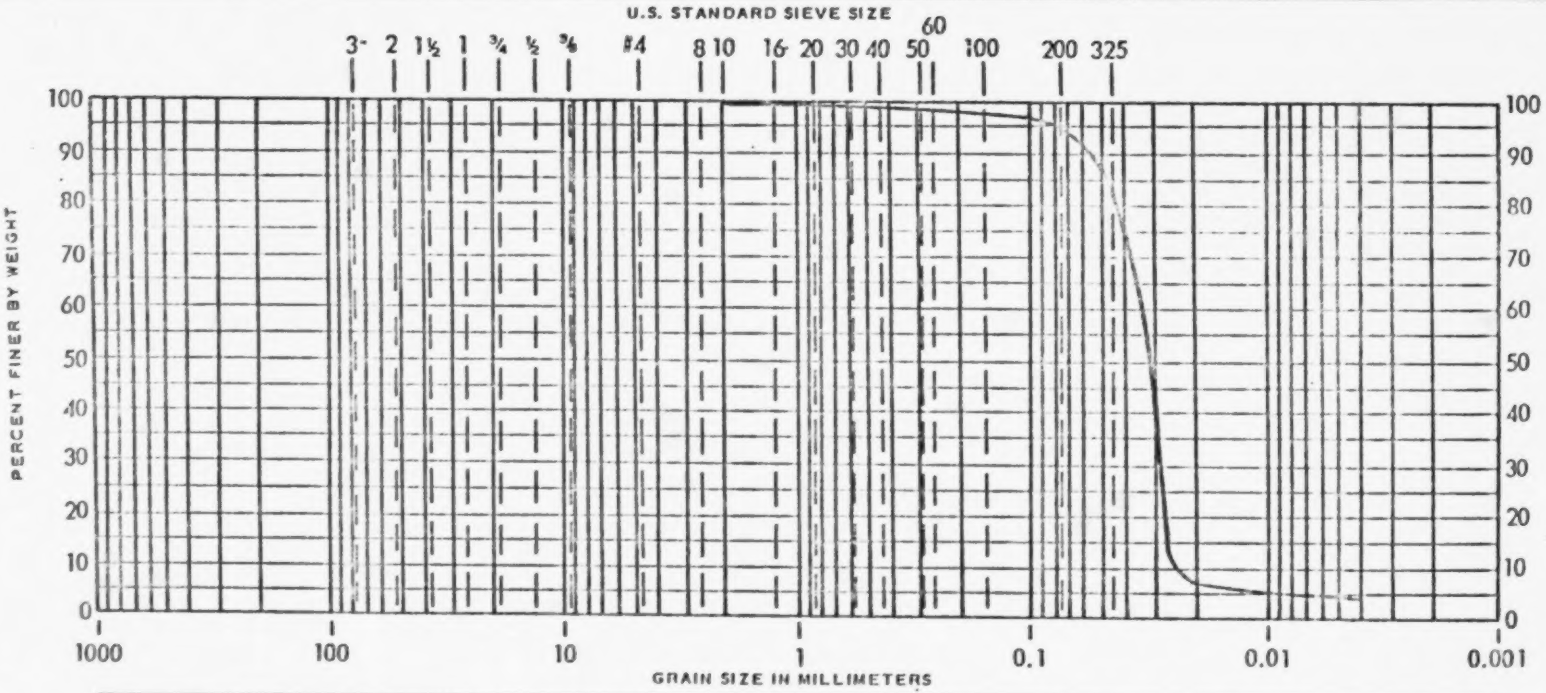
PROJECT Arthur D. Little
Sherco Site
BORING NO. 5-1
SAMPLE NO. S-2
DEPTH 8.5-10.5'
CLASSIFICATION "ML"

"SILT"

NATURAL % MOISTURE 35.2
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL		SAND 5%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	91%	4%

PROJECT Arthur D. Little,
Sherco Site
BORING NO. B5-1
SAMPLE NO. U2
DEPTH 16.5-18.5'
CLASSIFICATION "ML"

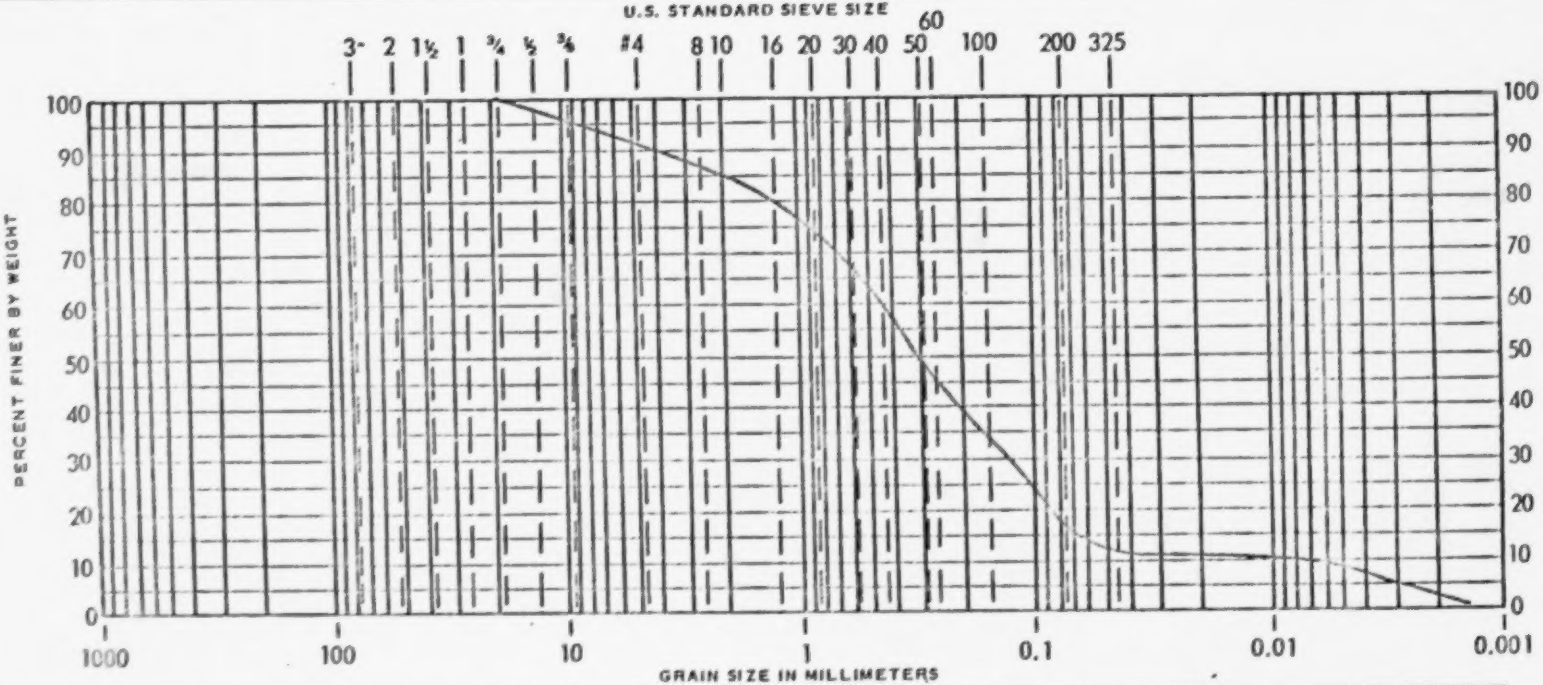
"SILT"

NATURAL % MOISTURE 43.5
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 9%		SAND 76%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	8%	7%

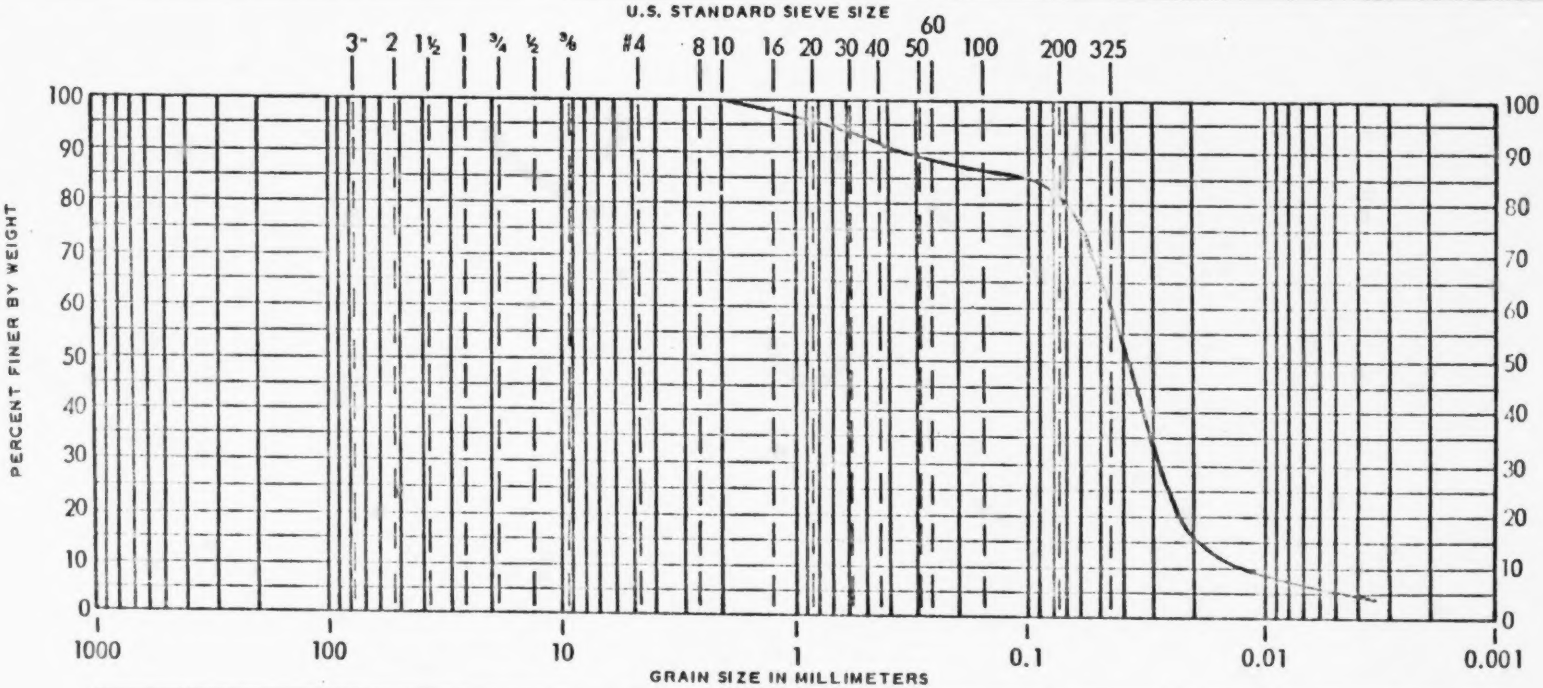
PROJECT Arthur D. Little,
Sherco Site
BORING NO. 5-1
SAMPLE NO. S-6
DEPTH 28.5-30.5'
CLASSIFICATION "SM"

silty "SAND"

NATURAL % MOISTURE 8.8
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



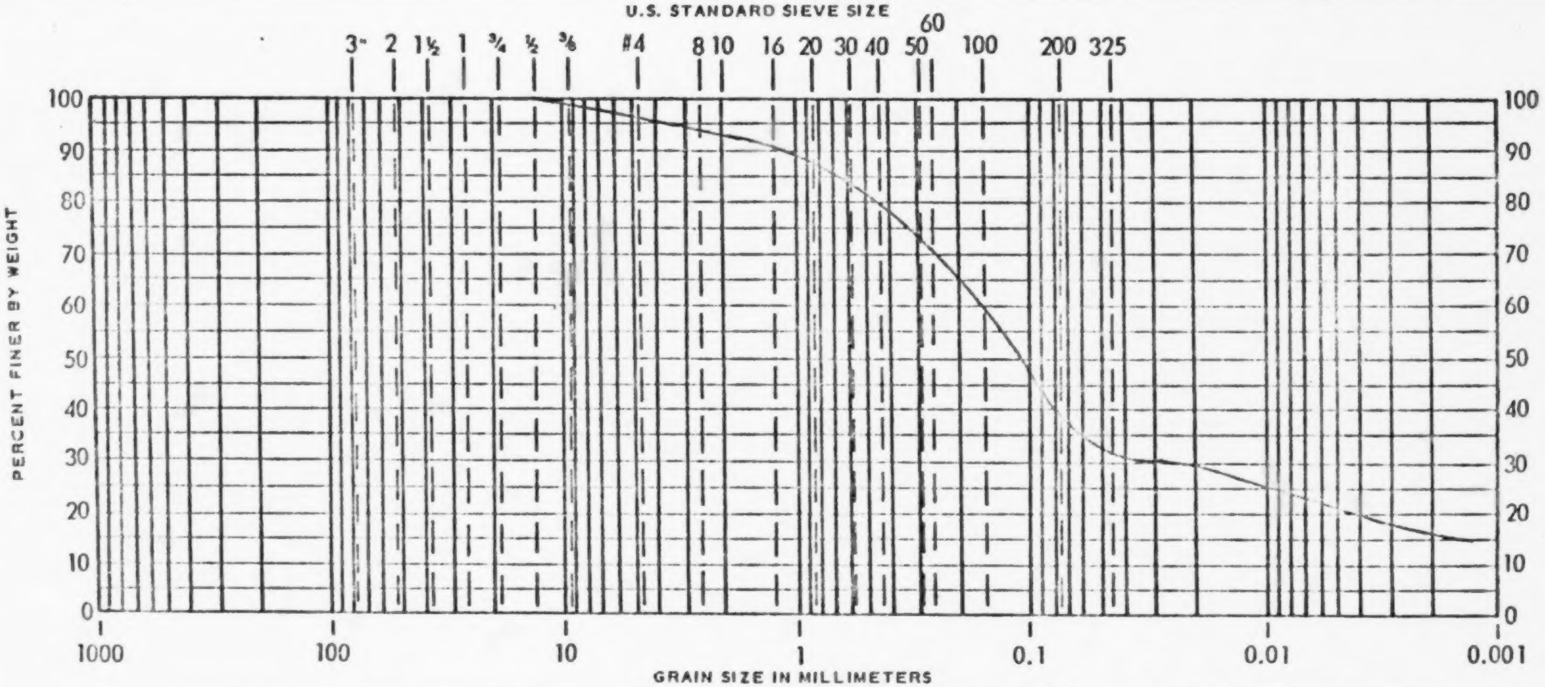
COBBLES	GRAVEL		SAND 17%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	78%	5%

PROJECT Arthur D. Little,
Sherco Site
BORING NO. 5-2
SAMPLE NO. U-1-A
DEPTH 6.5'-8.5'
CLASSIFICATION "ML"
Silt

NATURAL % MOISTURE 30.0
LIQUID LIMIT
PLASTIC LIMIT Tested Non-
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 3%		SAND 59%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	17%	21%

PROJECT Arthur D. Little,
Sherco Site
BORING NO. 5-2
SAMPLE NO. 6S
DEPTH 28.0-29.1'
CLASSIFICATION "SC"

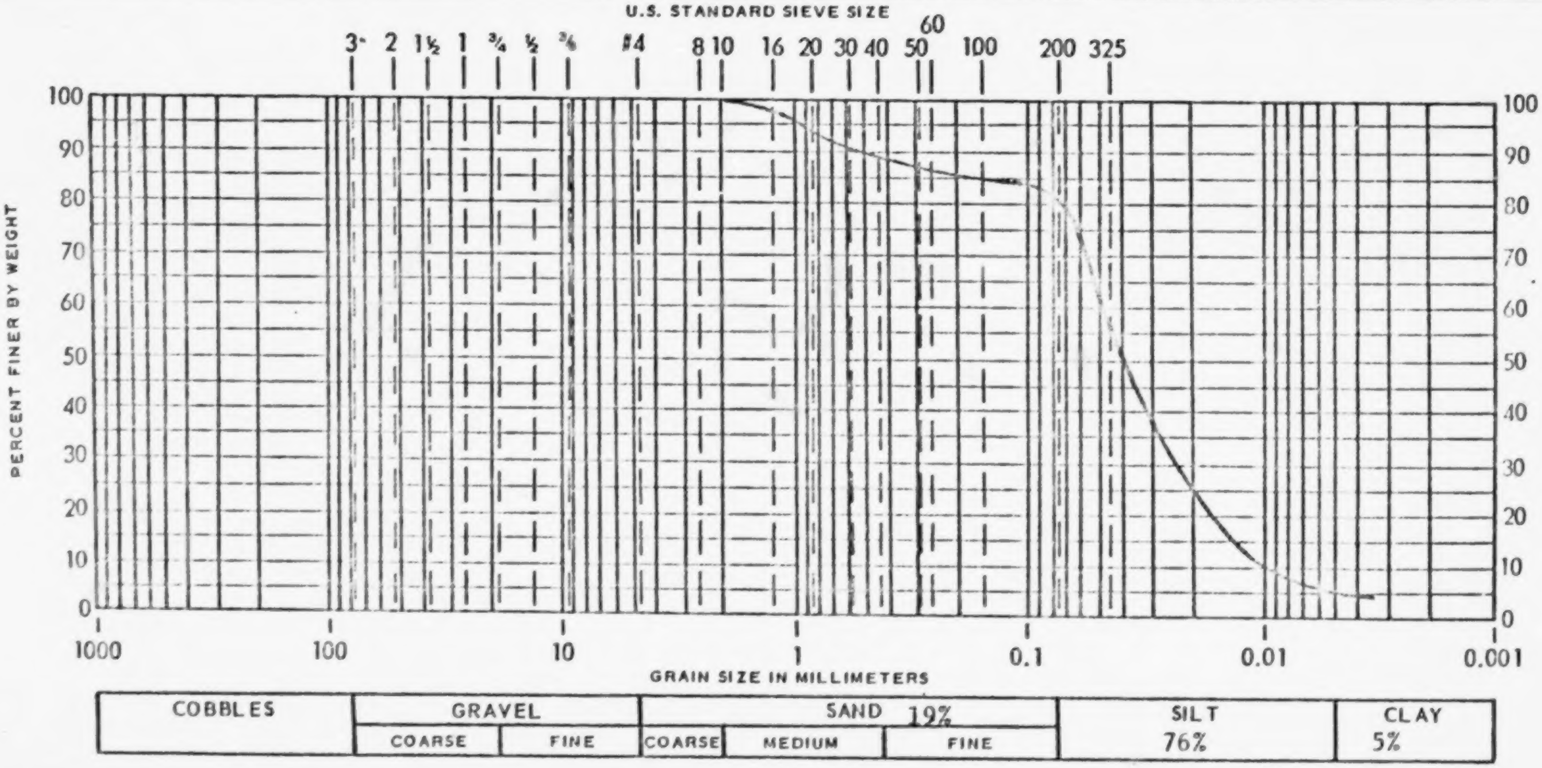
clayey "SAND"

NATURAL % MOISTURE 14.6
LIQUID LIMIT 32
PLASTIC LIMIT 23
PLASTICITY INDEX 9
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



PROJECT	Arthur D. Little, Sherco Site
BORING NO.	5-2A
SAMPLE NO.	U-1
DEPTH	6.5'-8.5'
CLASSIFICATION	"ML" Silt

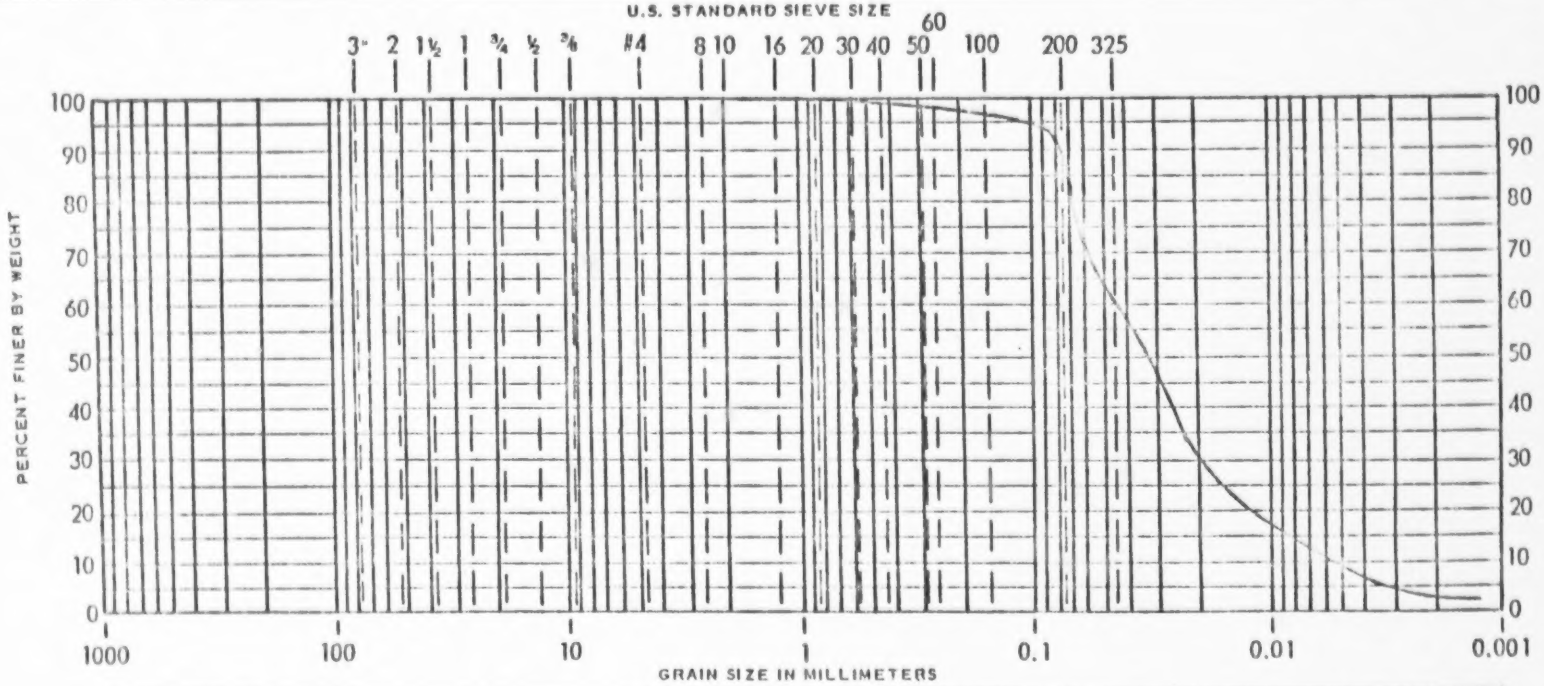
NATURAL % MOISTURE	27.2
LIQUID LIMIT	
PLASTIC LIMIT	Tested Non-
PLASTICITY INDEX	Plastic
COLOR	Gray
REMARKS	"U.S.C.S."

BOWSER-MORNER

TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 0%		SAND 9%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	82%	9%

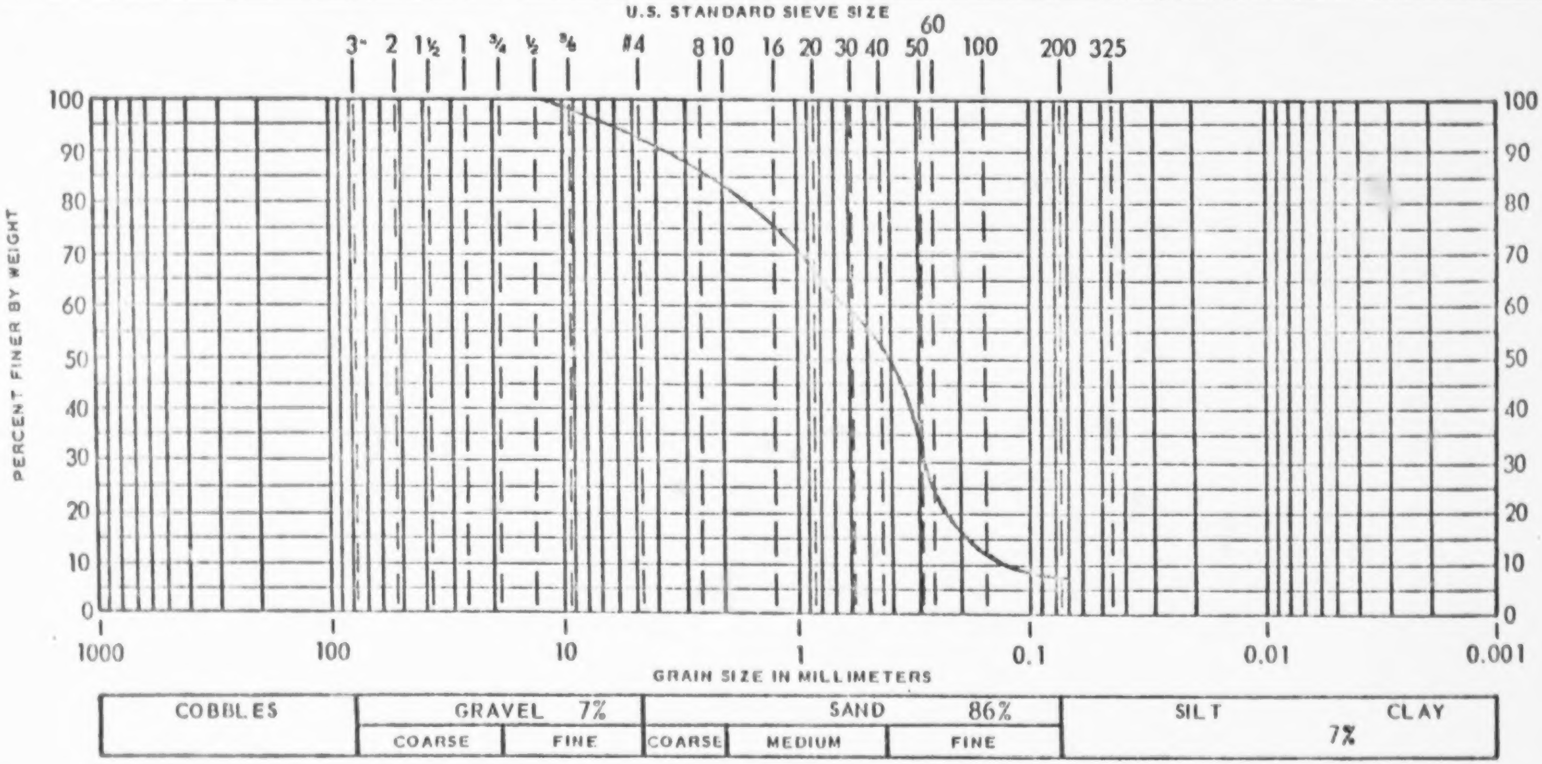
PROJECT Arthur D. Little
Sherco Site
BORING NO. 5-3
SAMPLE NO. S8
DEPTH 20.0-22.0'
CLASSIFICATION "ML"

"SILT"

NATURAL % MOISTURE 43.9
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET

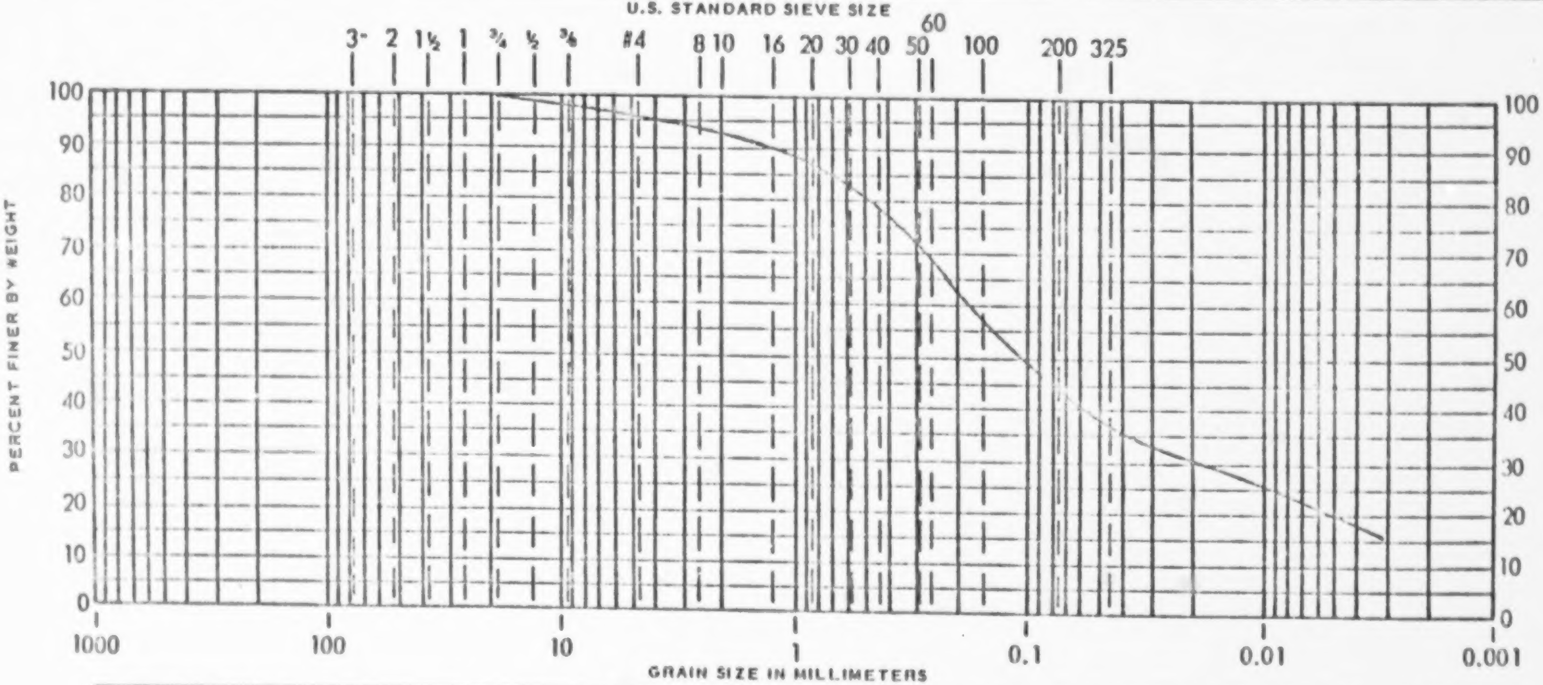


PROJECT Arthur D. Little,
Sherco Site
BORING NO. 5-3
SAMPLE NO. S14
DEPTH 38.0'-40.5'
CLASSIFICATION "SP-SM"
Poorly graded silty sand

NATURAL % MOISTURE 5.7
LIQUID LIMIT Visually
PLASTIC LIMIT Non-
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 4%		SAND 52%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	24%	20%

PROJECT Arthur D. Little,
Sherco Site
Clay Core Sample

DEPTH 4.0-6.0'
CLASSIFICATION "SM-SC"

silty, clayey "SAND"

NATURAL % MOISTURE	11.3
LIQUID LIMIT	25
PLASTIC LIMIT	18
PLASTICITY INDEX	7
COLOR	Brown
REMARKS	"U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SPECIFIC GRAVITY

Project: Arthur D. Little, Sherco Site

Boring No.:	B5-1
Sample No.:	U-2
Depth:	16.5' - 18.5'
Procedure:	ASTM-D854

TEST RESULTS

Specific Gravity:	2.34
Material Description:	FGD Sludge

SPECIFIC GRAVITY

Project: Arthur D. Little, Sherco Site

Boring No.: B5-2A

Sample No.: U-1

Depth: 6.5' - 8.5'

Procedure: ASTM-D854

TEST RESULTS

Specific Gravity: 2.36

Material Description: Flyash with FGD Sludge

SPECIFIC GRAVITY

Project: Arthur D. Little, Sherco Site

Boring No.: B5-3

Sample No.: S-7

Depth: 17.0' - 19.0'

Procedure: ASTM-D854

TEST RESULTS

Specific Gravity: 2.71

Material Description: Flyash with FGD Sludge

SPECIFIC GRAVITY

Project: Arthur D. Little, Sherco Site

Boring No.: B5-1

Sample No.: S-1

Depth: 4.5' - 6.0'

Procedure: ASTM-D854

TEST RESULTS

Specific Gravity: 2.73

Material Description: FGD Sludge

EXTENDED PERMEABILITY TEST

Project: Arthur D. Little, Sherco Site

Boring No.:	B5-1
Sample No.:	U2
Material:	FGD Sludge
Depth:	16.5' - 18.5'

SPECIMEN DATA

Initial Conditions,

Height:	3.728"
Diameter:	1.853"
Weight:	0.64 lbs.
Moisture Content:	43.5 %
Wet Unit Weight:	109.9 pcf
Dry Unit Weight:	76.6 pcf

Test Summary

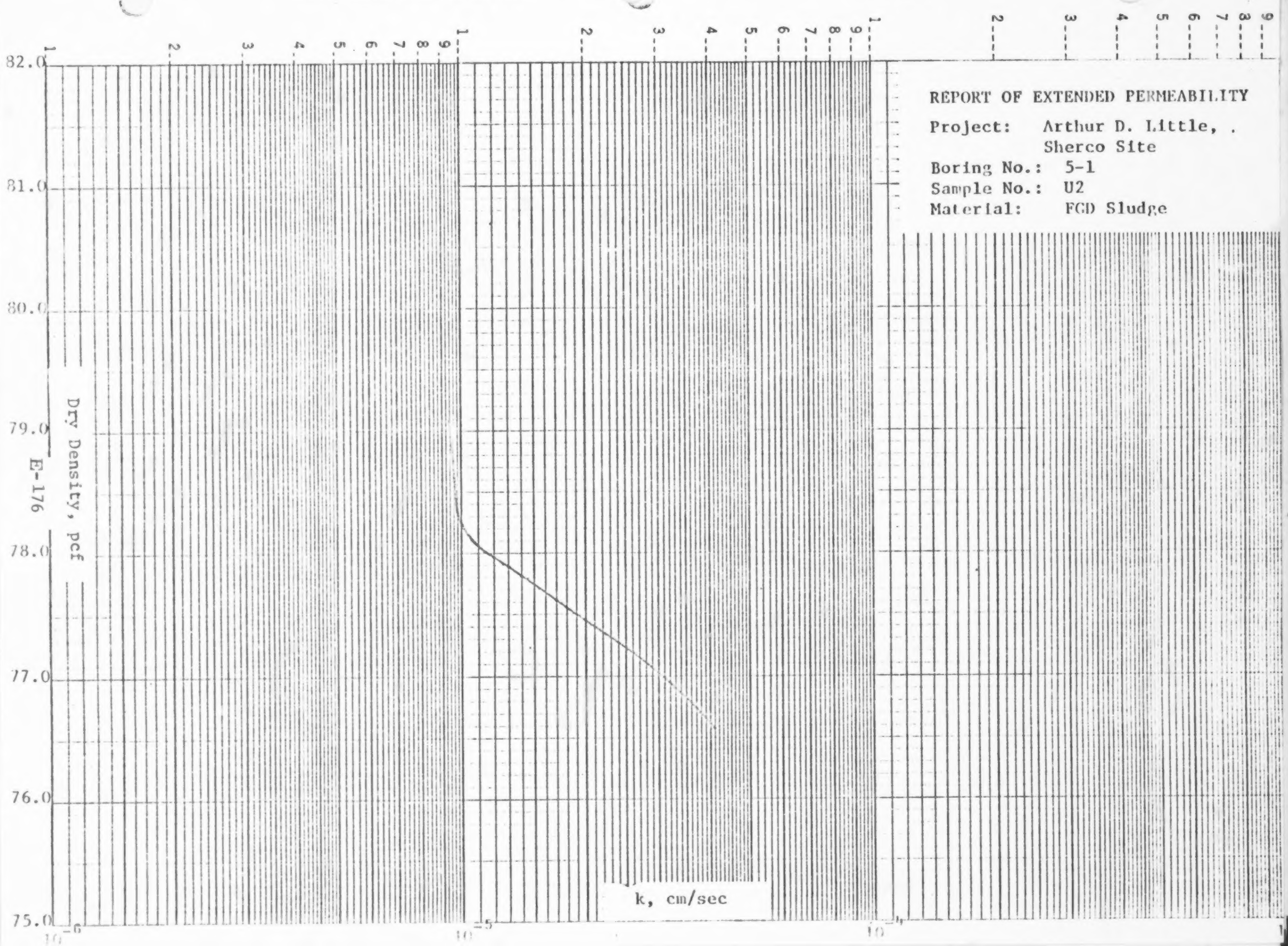
Graphical Presentation on Following Pages

Dry Unit Weight pcf	Permeability, k 10^{-5} cm/sec
76.6	4.1
77.0	3.1
77.5	1.9
78.2	1.0
79.1	0.94

K•E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 5506

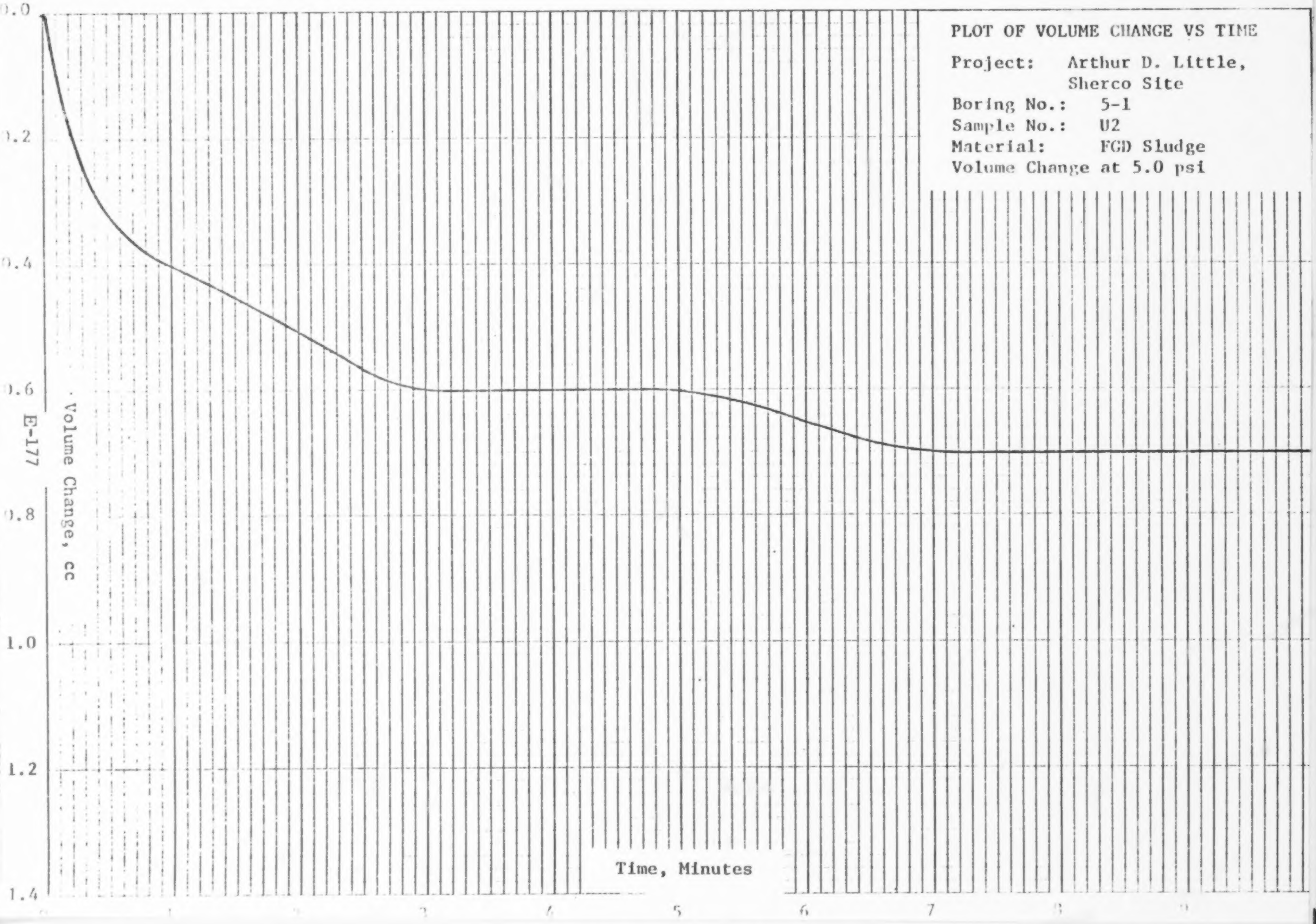
REPORT OF EXTENDED PERMEABILITY

Project: Arthur D. Little, .
Sherco Site
Boring No.: 5-1
Sample No.: U2
Material: FGD Sludge



K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0700

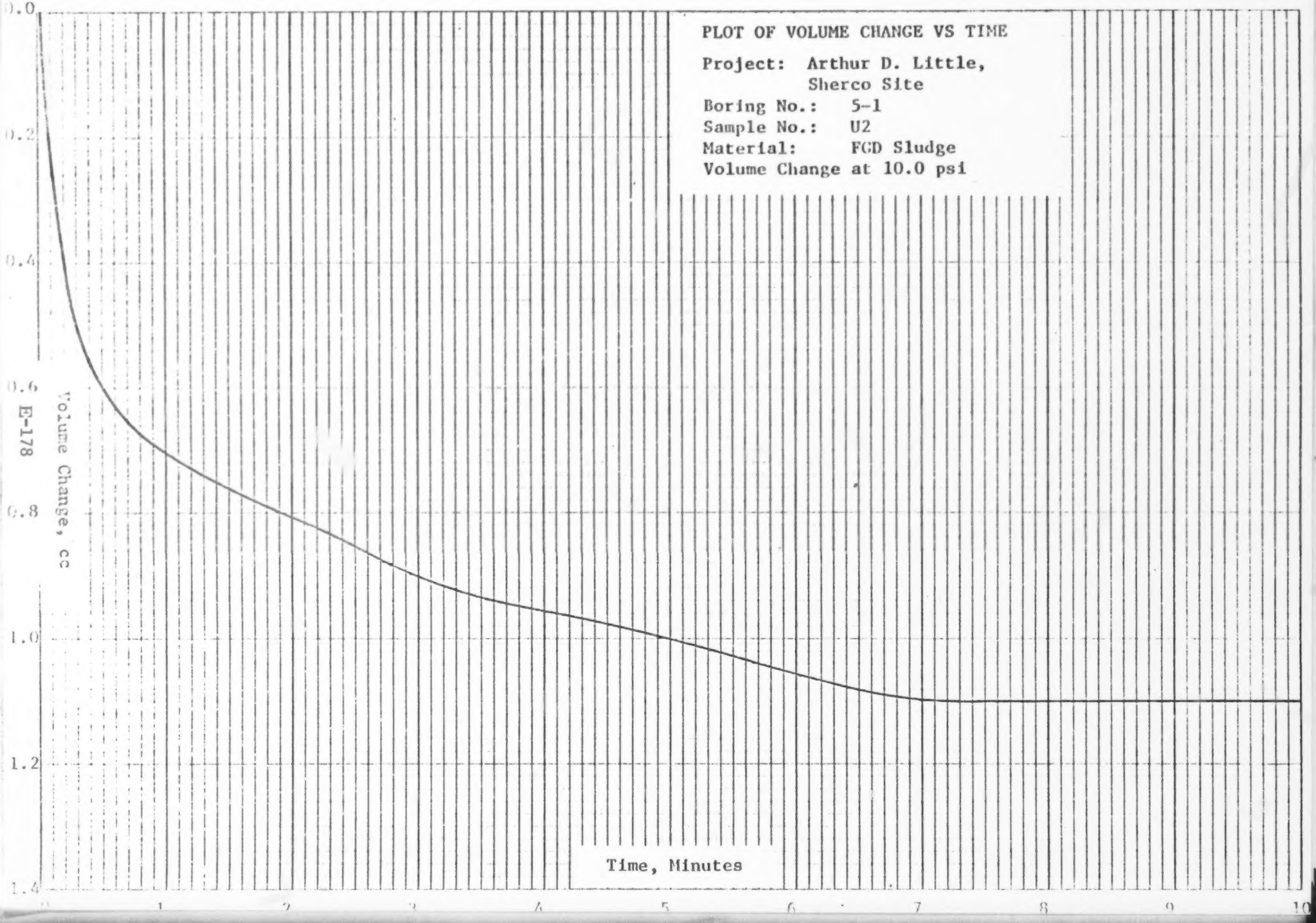


PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little,
Sherco Site
Boring No.: 5-1
Sample No.: U2
Material: FGD Sludge
Volume Change at 5.0 psi

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0700

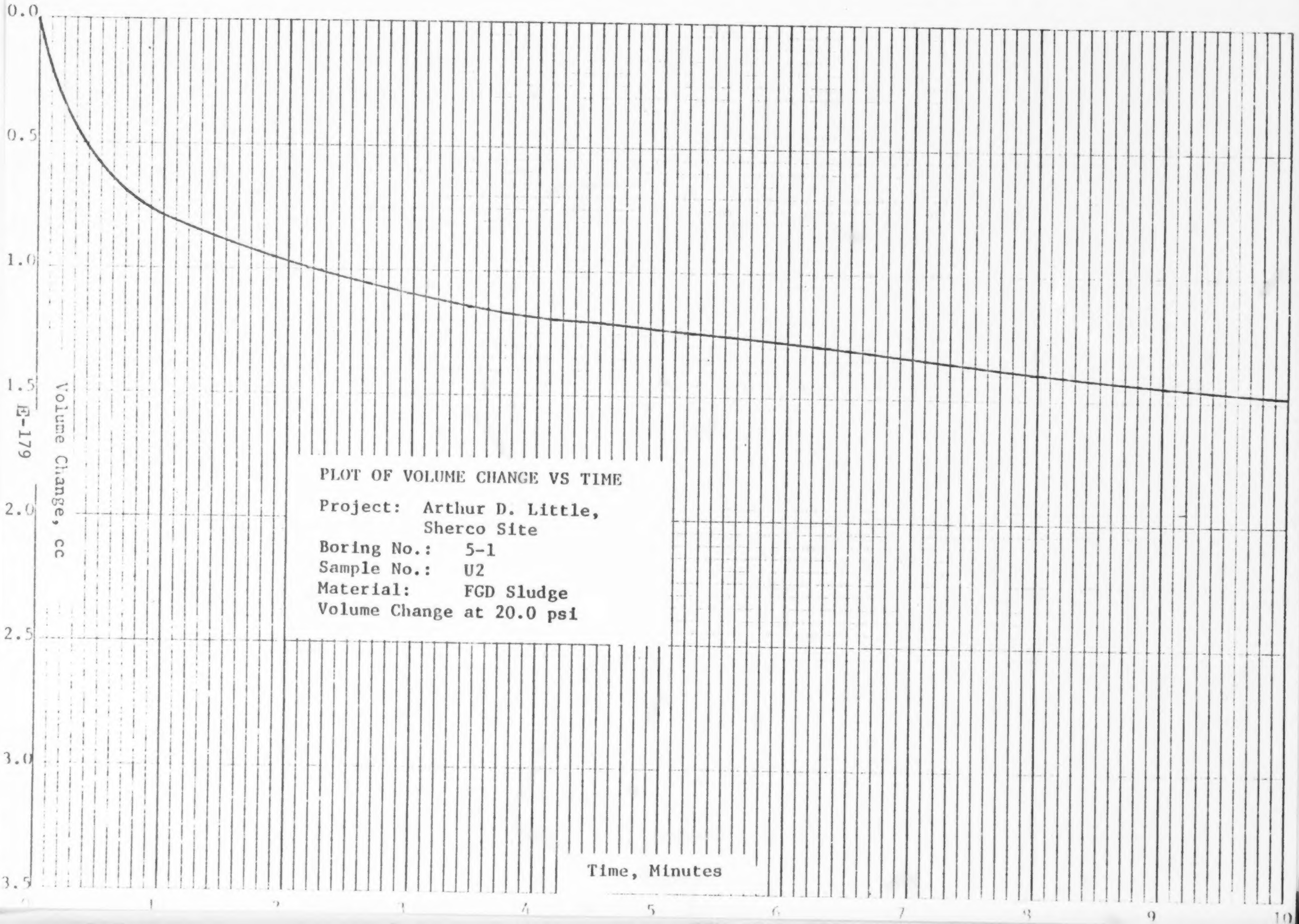


PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little,
Sherco Site
Boring No.: 5-1
Sample No.: U2
Material: FGD Sludge
Volume Change at 10.0 psi

K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0700

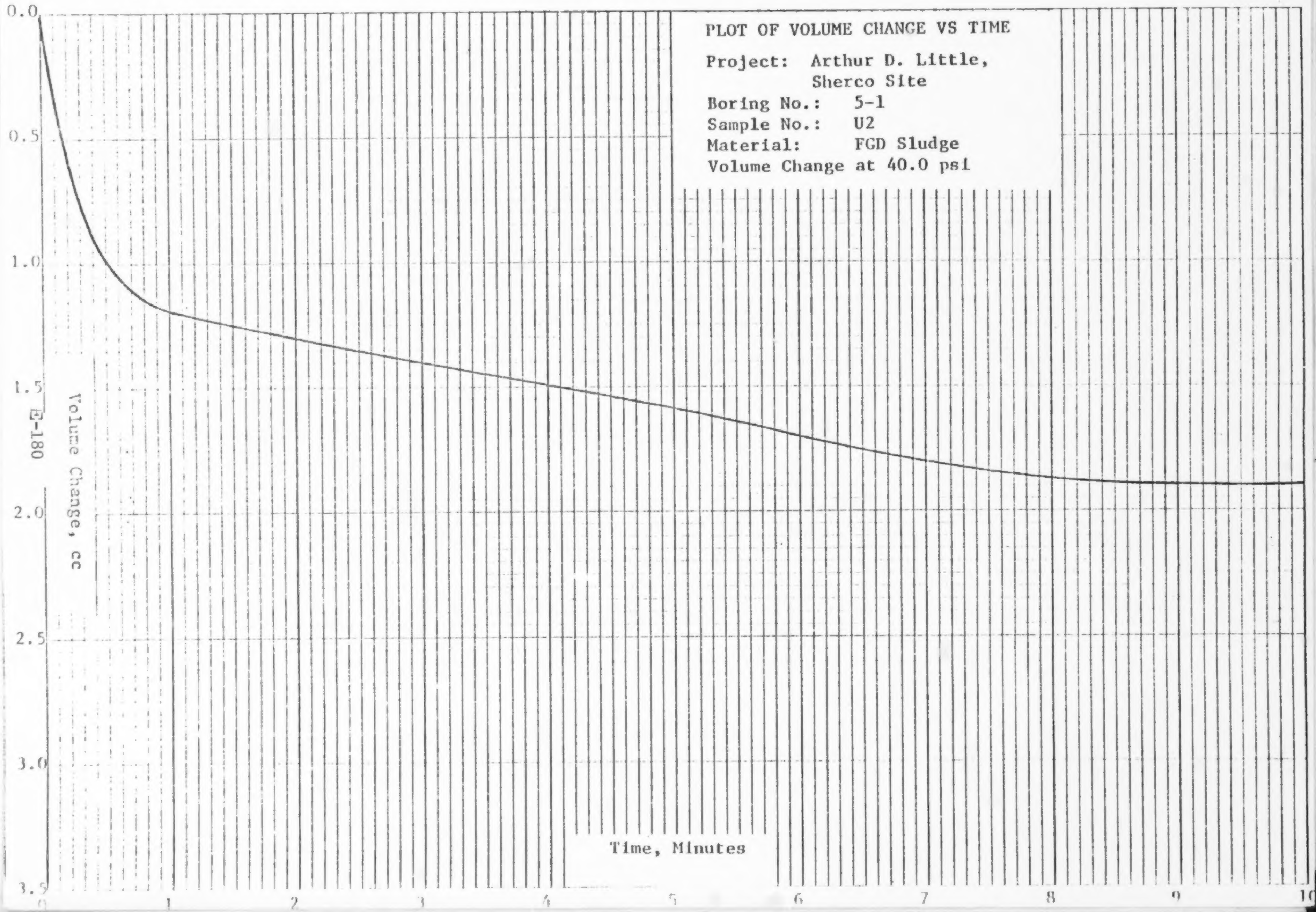


PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little,
Sherco Site
Boring No.: 5-1
Sample No.: U2
Material: FGD Sludge
Volume Change at 20.0 psi

K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0700



PLOT OF VOLUME CHANGE VS TIME

Project: Arthur D. Little,
Sherco Site
Boring No.: 5-1
Sample No.: U2
Material: FGD Sludge
Volume Change at 40.0 psi

Constant Head

Permeability Test

Project: Arthur D. Little, Sherco Site

Boring No.: B5-2

Sample No.: U-1-A

Depth Interval of Sample: 6.5' - 8.5'

Depth Interval of Test Specimen: 6.6' - 6.8'

SPECIMEN DATA:

Dimensions, inches,

Height: 2.323

Diameter: 2.880

Weight, lbs.,

Initial: 0.88

Moisture Content, %:

Initial: 30.0

Final: 30.7

Wet Unit Weight, pcf,

Initial: 100.5

Final: 101.0

Dry Unit Weight, pcf,

Initial: 77.3

Back Pressure Saturation, psi,

Pressures: 10.0

Material Description: FGD Sludge

Permeability, cm/sec,

k: 3×10^{-5}

Constant Head

Permeability Test

Project: Arthur D. Little, Sherco Site

Boring No.: B5-2

Sample No.: U3

Depth Interval of Sample: 24.5' - 26.5'

Depth Interval of Test Specimen: 24.6' - 24.8'

SPECIMEN DATA:

Dimensions, inches,

Height: 2.725

Diameter: 1.879

Weight, lbs.,

Initial: 0.43

Moisture Content, %:

Initial: 41.1

Final: 43.0

Wet Unit Weight, pcf,

Initial: 98.3

Final: 99.7

Dry Unit Weight, pcf,

Initial: 69.7

Back Pressure Saturation, psi,

Pressures: 10.0

Material Description: FGD Sludge

Permeability, cm/sec,

k: 5×10^{-6}

Constant Head

Permeability Test

Project: Arthur D. Little, Sherco Site

Boring No.: B5-2

Sample No.: S6

Depth Interval of Sample: 28.0' - 29.1'

SPECIMEN DATA:

Dimensions, inches,

- Height: 2.740
- Diameter: 1.386

Weight, lbs.,

- Initial: 0.32

Moisture Content, %:

- Initial: 14.6
- Final: 18.8

Wet Unit Weight, pcf, -

- Initial: 133.8
- Final: 138.7

Dry Unit Weight, pcf,

- Initial: 116.7

Back Pressure Saturation, psi,

- Pressures: 10.0

Material Description: Brown sand, some clay, trace silt

Permeability, cm/sec,

- k: 2×10^{-6}

Constant Head

Permeability Test

Project:	Arthur D. Little, Sherco Site
Boring No.:	5-2B
Sample No.:	U1
Depth Interval of Sample:	6.5' - 8.5'
Depth Interval of Test Specimen:	7.5' - 7.7'
Material:	Light gray FGD sludge
SPECIMEN DATA:	
Dimensions, inches,	
Height:	2.028"
Diameter:	2.840"
Weight, lbs.,	
Initial:	0.91
Moisture Content, %:	
Initial:	43.7
Final:	32.0
Wet Unit Weight, pcf,	
Initial:	122.4
Final:	112.5
Dry Unit Weight, pcf,	
Initial:	85.2
Back Pressure Saturation, psi,	
Pressures:	10.0
Permeability, cm/sec,	
k:	2×10^{-5}

Constant Head

Permeability Test

Project: Arthur D. Little, Sherco Site

Boring No.:	Clay Core
Sample No.:	1C
Depth Interval of Sample:	4.0' - 6.0'
Depth Interval of Test Specimen:	4.1' - 4.3'
SPECIMEN DATA:	
Dimensions, inches,	
Height:	2.093
Diameter:	2.858
Weight, lbs.,	
Initial:	1.07
Moisture Content, %:	
Initial:	11.3
Final:	14.7
Wet Unit Weight, pcf,	
Initial:	137.7
Final:	141.9
Dry Unit Weight, pcf,	
Initial:	123.7
Back Pressure Saturation, psi,	
Pressures:	10.0
Material Description:	Brown clay, some silt, some sand, trace gravel
Permeability, cm/sec,	
k:	1 x 10-7

LABORATORY SUMMARY SHEET

Arthur D. Little, Sherco Site

Page 1 of 5

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
B5-1	S1	4.5-6.0					27.8			
	S2	8.5-10.5		Tested Non-Plastic			35.2			"ML"
	U2	16.5-18.5	Permeability	Visually Non-Plastic			43.5	76.6		"ML"
	S5	26.5-27.0					Saturated			
	S6	28.5-30.5		Tested Non-Plastic			8.8			"SM"
	S7	30.5-32.5					5.1			
B5-2	U1A	6.5-8.5	Permeability	Tested Non-Plastic			30.0	77.3		"ML"
	S1	8.5-10.5					29.0			
	S2	10.5-12.5					41.4			
	S3	14.5-16.5					42.4			
	S5	20.5-22.5					Saturated			
	U3	24.5-26.5	Permeability				41.1	69.7		
	S6	28.0-29.1	Permeability	32	23	9	14.6	116.7		"SC"
B5-2A	U1	6.5-8.5		Tested Non-Plastic			27.2	83.4		"ML"
B5-2B	U1	6.5-8.5	ON HOLD				----			
B5-3	S1	0.0-2.0					23.5			
	S2	4.0-6.0					20.5			
	S3	6.0-8.0					32.9			
	S4	8.0-10.0					26.7			
	S6	15.0-17.0					35.0			
	S7	17.0-19.0					Saturated			
	S8	20.0-22.0		Tested Non-Plastic			43.9			"ML"
	S10	27.0-29.0					32.9			
	S14	38.0-40.5		Visually Non-Plastic			5.7			"SP-SM"

E=186

BOWSER-MORNER
Testing Laboratories, Inc

LABORATORY SUMMARY SHEET

Arthur D. Little, Sherco Site

Page 2 of 5

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
B5-4	1S	1.0-2.5					4.7			
	2S	4.0-5.5					4.8			
	3S	9.0-10.5					5.1			
	4S	14.0-15.0					4.6			
	5S	19.0-20.0					7.0			
	6S	24.0-25.5					8.5			
	7S	29.0-30.5					3.2			
	11S	44.0-45.5					Saturated			
	12S	49.0-50.0					Saturated			
	13S	54.0-55.0					Saturated			
	14S	59.0-60.0					Saturated			
	15S	64.0-65.0					Saturated			
B5-5	1S	3.0-4.5					2.9			
	2S	9.0-10.5					4.8			
	4S	34.0-34.5					4.2			
	5S	39.0-40.5					Saturated			
	6S	49.0-50.0					Saturated			
	7S	54.0-55.0					Saturated			
	8S	59.0-60.5					Saturated			
	9S	69.0-70.0					Saturated			
B5-6	1S	1.0-2.5					9.3			
	1B	4.0-5.5					10.9			
	2S	9.0-10.5					----			
	3S	14.0-15.5					6.4			
	4S	19.0-20.5					1.4			
	5S	24.0-25.5					2.9			
	6S	29.0-30.5					4.4			
	7S	34.0-35.5					9.8			
	8S	39.0-40.0					Saturated			

LABORATORY SUMMARY SHEET

Arthur D. Little, Sherco Site

Page 3 of 5

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
	9S	44.0-45.5					Saturated			
	10S	49.0-50.0					Saturated			
	11S	54.0-55.0					Saturated			
B5-7	1S	1.0-2.5					4.8			
	2S	4.0-5.5					5.6			
	3S	9.0-10.5					4.7			
	4S	14.0-15.5					15.7			
	5S	19.0-20.5					20.3			
	6S	24.0-25.5					3.3			
	7S	29.0-30.0					3.6			
	8S	34.0-35.0					2.9			
	9S	39.0-40.5					Saturated			
	10S	44.0-45.0					Saturated			
	14S	64.0-64.5					Saturated			
B5-8	1S	1.0-2.5					7.0			
	2S	4.0-5.5					6.6			
	3S	9.0-9.5					5.8			
	4S	19.0-20.5					2.4			
	5S	29.0-29.5					----			
	7S	37.0-38.5					Saturated			
	8S	44.0-45.0					Saturated			
B5-9	1S	1.0-2.5					4.6			
	2S	4.0-5.5					3.4			
	3S	9.0-10.5					4.4			
	4S	14.0-15.5					1.6			
	5S	19.0-20.5					6.1			
	6S	24.0-24.5					6.2			
	7S	29.0-30.0					3.1			
	8S	34.0-35.0					Saturated			
	9S	39.0-40.0					Saturated			

LABORATORY SUMMARY SHEET

Arthur D. Little, Sherco Site

Page 4 of 5

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
	10S	44.0-45.5					Saturated			
	12S	54.0-55.0					Saturated			
	13S	59.0-60.0					Saturated			
	14S	64.0-65.0					Saturated			
	15S	69.0-69.5					Saturated			
	16S	74.0-74.5					Saturated			
	17S	79.0-80.0					Saturated			
	18S	84.0-84.5					Saturated			
	19S	89.0-90.0					Saturated			
B5-10	1S	1.0-2.5					3.2			
	2S	4.0-5.5					2.9			
	3S	9.0-10.5					4.6			
	4S	14.0-15.5					3.2			
	5S	19.0-20.5					5.6			
	6S	24.0-25.0					11.9			
	7S	29.0-30.0					2.9			
	8S	34.0-35.0					3.7			
	9S	39.0-40.5					Saturated			
	10S	44.0-45.0					Saturated			
	11S	49.0-50.0					Saturated			
	12S	54.0-55.0					Saturated			
	13S	59.0-60.0					Saturated			
B5-11	1S	1.0-2.5					11.3			
	2S	4.0-5.5					4.0			
	3S	9.0-10.5					2.5			
	4S	14.0-15.5					3.3			
	5S	19.0-20.5					2.6			
	6S	24.0-25.5					5.4			
	7S	29.0-30.5					6.4			

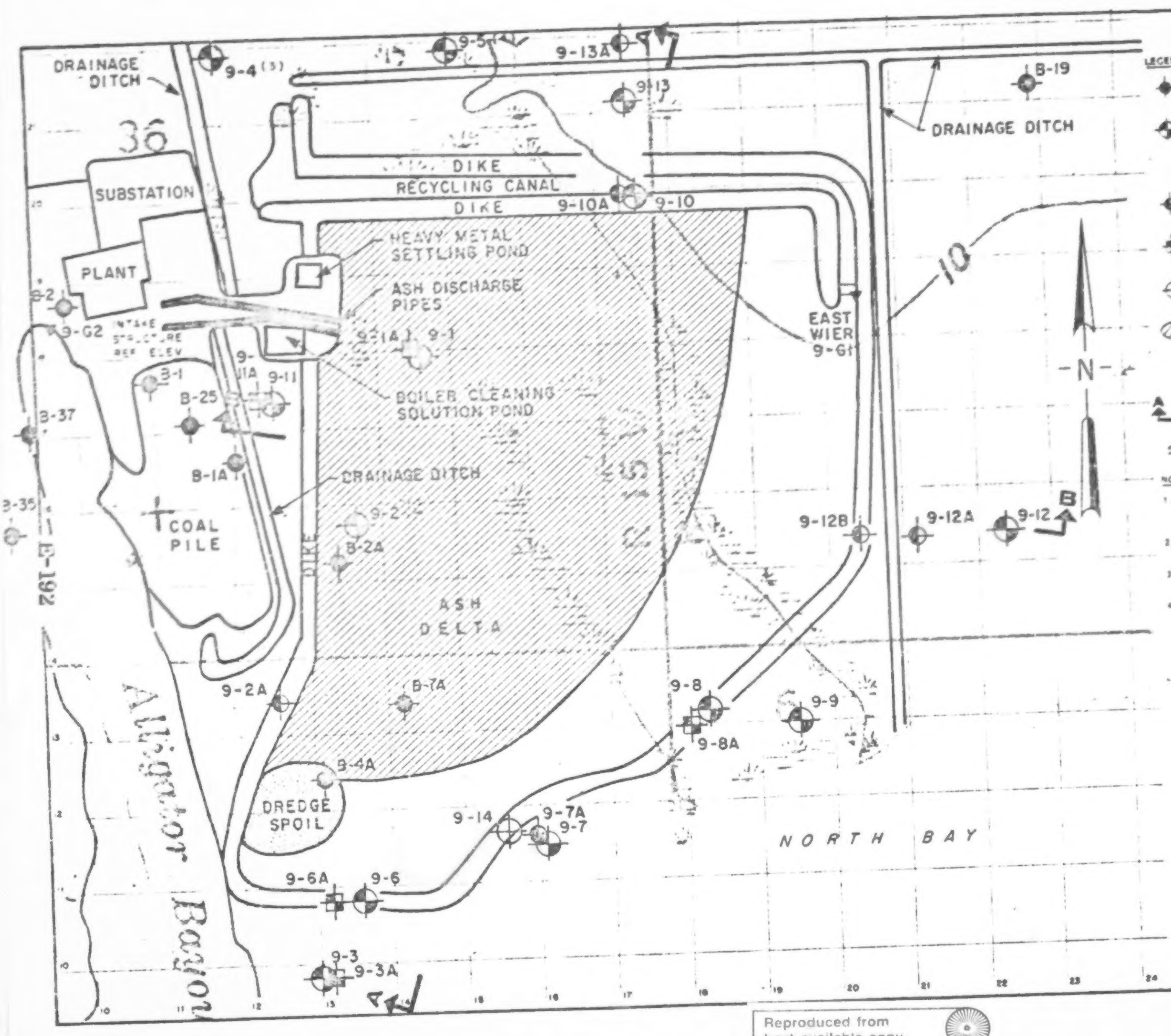
LABORATORY SUMMARY SHEET

Arthur D. Little, Sherco Site

Page 5 of 5

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
	8S	34.0-35.5					4.3			
	9S	39.0-40.5					10.1			
	10S	44.0-45.0					Saturated			
	12S	54.0-55.0					Saturated			
	13S	59.0-60.5					Saturated			
Clay core in dike										
	1C	4.0-6.0	Permeability	25	18	7	11.3	123.7		"SM-SC"
	1B	3.0-9.5	ON HOLD				----			

Lansing Smith Gulf Power


DRAINAGE DITCH
36
SUBSTATION
PLANT
INTAKE STRUCTURE REF. ELEV.
B-2
9-G2
B-1
B-25
B-37
B-1A
B-35
COAL PILE
E-192
Alligator Bayou
9-4 (3)
9-5
9-13A
9-13
DIKE
RECYCLING CANAL
DIKE
9-10A
9-10
HEAVY METAL SETTLING POND
ASH DISCHARGE PIPES
9-1A
9-1
9-11
BOILER CLEANING SOLUTION POND
DRAINAGE DITCH
9-2
B-2A
DIKE
ASH DELTA
9-2A
B-7A
B-4A
DREDGE SPOIL
9-6A
9-6
9-3
9-3A
A
9-14
9-7A
9-7
9-8
9-8A
9-9
NORTH BAY
9-12B
EAST WIER
9-G1
10
DRAINAGE DITCH
B-19
9-12A
9-12
B
N
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11
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24

LEGEND:

- B-2 — APPROXIMATE LOCATION OF SOIL BORING MADE IN THE SITE AREA IN 1961 BY LAW ENGINEERING TESTING COMPANY
- 9-11 — LOCATION OF ADL GEOTECHNICAL HYDROGEOLOGICAL CHEMICAL EXPLORATION WITH SELECTED 5 cm. (2 in.) DIAMETER P.V.C. OBSERVATION SAMPLING WELL INSTALLATION OR 2.5 cm. (1 in.) BY 122 cm. (4 ft.) LONG PIEZOMETER. REFER TO TABLE 3.2-1 FOR ADDITIONAL DETAILS.
- 9-2A — LOCATION OF ADL MACHINE DRIVEN 5 cm. (2 in.) GALVANIZED STEEL WELL POINT. REFER TO TABLE 3.2-1 FOR ADDITIONAL DETAILS.
- 9-3A — LOCATION OF ADL MACHINE DRIVEN 5 cm. (2 in.) P.V.C. WELL POINTS. REFER TO TABLE 3.2-1 FOR ADDITIONAL DETAILS.
- 9-14 — LOCATION OF ADL GEOTECHNICAL CHEMICAL EXPLORATION. REFER TO TABLE 3.2-1 FOR ADDITIONAL DETAILS.
- ▨ — ASH DELTA AREA
- 9-G1 — LOCATION OF REFERENCE ELEVATION (MSL DATUM) FROM WHICH ELEVATIONS OF THE TIDAL WATERS OF ALLIGATOR BAYOU AND THE SURFACE WATER IN THE ASH POND WERE MEASURED
- A A — INDICATES DIAGRAMMATIC SUBSURFACE PROFILE LINE
- 21/10 — PROJECT REFERENCE GRID

NOTES

1. BASE MAP FROM U.S.G.S. TOPOGRAPHIC MAP, SOUTHPORT QUADRANGLE, SCALE 1:24,000, DATE 1963. CONTOUR INTERVAL 10 FEET.
2. LOCATIONS OF EXISTING FEATURES ARE BASED ON AVAILABLE INFORMATION AND ARE APPROXIMATE.
3. ADL EXPLORATION 9-4 LOCATED 1520± FT. NORTH-WEST OF THE NW CORNER OF THE POWER PLANT BUILDING.
4. ADL EXPLORATION 9-5 LOCATED 2230± FT. NORTH NORTH-WEST OF THE NW CORNER OF THE POWER PLANT BUILDING.

DRAFT

SITE EVALUATION PLAN
SITE NUMBER 9

LANSING SMITH STEAM PLANT
GULF POWER COMPANY
PANAMA CITY
BAY COUNTY
FLORIDA

APPROX SCALE: 1:6,000
1 CM = 60 METERS
1 IN = 150 METERS (495 FEET)

FEBRUARY 1982

FIGURE 3.2-1

Reproduced from best available copy.

SUMMARY OF RESULTS

QA/QC PHYSICAL PROPERTY TESTS

SMITH SITE

Boring No.: 9-1

Sample No.: T1

Depth: 9.0' - 11.0'

Date of Sampling: December 18, 1981

Results of permeability tests on remolded compacted samples

Depth Interval (ft.)	Material	Water Content (%)	Moist Density (pcf)	Dry Density (pcf)	Coefficient of Permeability (cm/sec)
9.0-9.5	flyash	28.6			
9.5-10.0	flyash	32.2	111.1	83.6	10.5×10^{-4}
10.0-10.5	flyash	27.3	111.1	88.6	8.36×10^{-4}
10.5-11.0	flyash	14.4			

Constant Head Permeability Test

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No: 9-3

Sample No: T1

Depth Interval of Sample: 9.5'-11.5'

Depth Interval of Test Specimen: 9.5'-9.7'

Material Description: Brown sand, some silt

SPECIMEN DATA:

Dimensions, inches,

Height: 2.000
Diameter: 1.961

Weight, lbs.,

Initial: 0.44

Moisture Content, %:

Initial: 26.8
Final: 23.2

Wet Unit Weight, pcf,

Initial 124.3
Final: 120.8

Dry Unit Weight, pcf,

Initial 98.0

Back Pressure Saturation, psi,

Pressures: 30.0

Permeability, cm/sec,

k: 2.6×10^{-7}

Constant Head
Permeability Test

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No: 9-5

Sample No: U1

Depth Interval of Sample: 4.5'-6.5'

Depth Interval of Test Specimen: 4.5'-4.7'

Material Description: Brown Sand, Trace Silt

SPECIMEN DATA:

Dimensions, inches,

Height: 2.000
Diameter: 2.843

Weight, lbs.,

Initial: 0.74

Moisture Content, %:

Initial: 8.4
Final: 22.6

Wet Unit Weight, pcf,

Initial 100.9
Final: 114.2

Dry Unit Weight, pcf,

Initial 93.1

Back Pressure Saturation, psi,

Pressures: 10.0

Permeability, cm/sec,

k: 1.2×10^{-5}

Constant Head
Permeability Test

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No: 9-6

Sample No: U1

Depth Interval of Sample: 4.5'-6.5'

Depth Interval of Test Specimen: 5.5'-5.7'

Material Description: Brown Bottom Ash

SPECIMEN DATA:

Dimensions, inches,

Height: 2.000
Diameter: 2.852

Weight, lbs.,

Initial: 0.75

Moisture Content, %:

Initial: 6.5
Final: 22.7

Wet Unit Weight, pcf,

Initial 100.7
Final: 116.1

Dry Unit Weight, pcf,

Initial 94.6

Back Pressure Saturation, psi,

Pressures: 10.0

Permeability, cm/sec,

k: 7.5×10^{-7}

Constant Head
Permeability Test

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No:	9-6
Sample No:	U2
Depth Interval of Sample:	9.5'-11.5'
Depth Interval of Test Specimen:	9.5'-9.7'
Material Description:	Gray Bottom Ash

SPECIMEN DATA:

Dimensions, inches,	
Height:	2.000
Diameter:	2.873
Weight, lbs.,	
Initial:	0.84
Moisture Content, %:	
Initial:	14.2
Final:	21.8
Wet Unit Weight, pcf,	
Initial	111.3
Final:	118.7
Dry Unit Weight, pcf,	
Initial	97.5
Back Pressure Saturation, psi,	
Pressures:	20.0
Permeability, cm/sec,	
k:	7.3×10^{-6}

Constant Head
Permeability Test

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No:	9-8
Sample No:	U2
Depth Interval of Sample:	9.5'-11.5'
Depth Interval of Test Specimen:	9.7'-9.9'
Material Description:	Brown Sand, Trace Silt

SPECIMEN DATA:

Dimensions, inches,	
Height:	2.000
Diameter:	2.842
Weight, lbs.,	
Initial:	0.86
Moisture Content, %:	
Initial:	13.7
Final:	23.3
Wet Unit Weight, pcf,	
Initial	117.3
Final:	127.3
Dry Unit Weight, pcf,	
Initial	103.2
Back Pressure Saturation, psi,	
Pressures:	10.0
Permeability, cm/sec,	
k:	1.3×10^{-5}

Constant Head
Permeability Test

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No:	9-10
Sample No:	U2
Depth Interval of Sample:	9.5'-11.5'
Depth Interval of Test Specimen:	9.5'-9.7'
Material Description:	Brown and gray sand, trace silt

SPECIMEN DATA:

Dimensions, inches,	
Height:	2.868
Diameter:	2.000
Weight, lbs.,	
Initial:	0.87
Moisture Content, %:	
Initial:	12.7
Final:	20.7
Wet Unit Weight, pcf,	
Initial	116.1
Final:	124.3
Dry Unit Weight, pcf,	
Initial	103.0
Back Pressure Saturation, psi,	
Pressures:	10.0
Permeability, cm/sec,	
k:	2.8×10^{-6}

Constant Head
Permeability Test
Laboratory Compacted

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No: 9-6

Sample No: U1

Depth Interval of Sample: 4.5'-6.5'

Depth Interval of Test Specimen: 4.5'-4.7'

Material Description: Gray Fly Ash

SPECIMAN DATA:

Dimensions, inches,

Height: 2.350
Diameter: 2.802

Weight, lbs.,

Initial: 0.653

Moisture Content, %:

Initial: 63.3
Final: 81.1

Wet Unit Weight, pcf,

Initial: 77.9
Final: 86.4

Dry Unit Weight, pcf,

Initial: 47.7

Back Pressure Saturation, psi,

Pressures: 10.0

Permeability, cm/sec,

k: 7.08×10^{-5}

Constant Head Permeability Test Laboratory Compacted

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No: 9-10

Sample No: S2

Depth Interval of Sample: 6.5'-8.5'

Depth Interval of Test Specimen: Remolded (compacted, loose)

Material Description: Gray/Brown Ash

SPECIMAN DATA:

Dimensions, inches,

Height: 2.000
Diameter: 2.830

Weight, lbs.,

Initial: 0.573

Moisture Content, %:

Initial: 27.5
Final: 27.5

Wet Unit Weight, pcf,

Initial: 78.6
Final: 96.2

Dry Unit Weight, pcf,

Initial: 61.7

Back Pressure Saturation, psi,

Pressures: 10.0

Permeability, cm/sec,

k: 3.00×10^{-5}

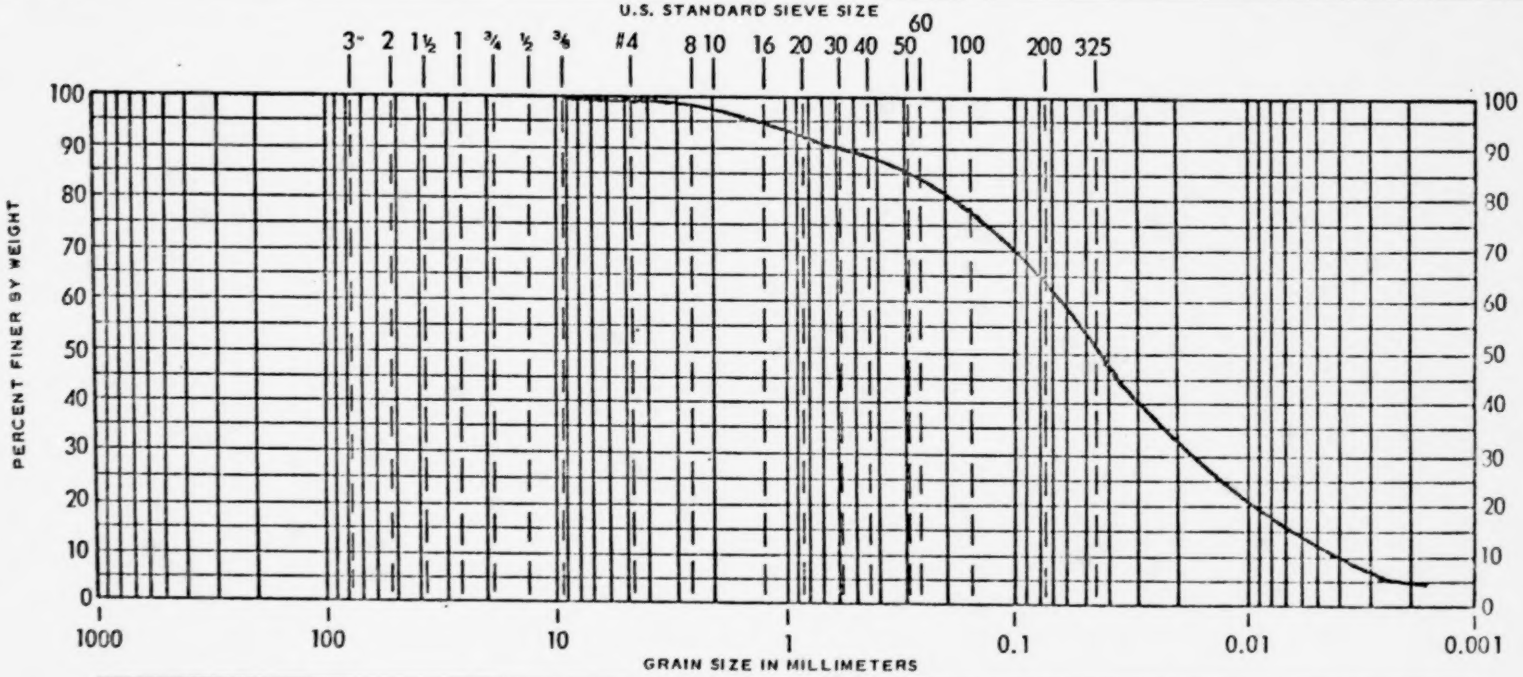
Constant Head
Permeability Test
Laboratory Compacted

Project: Arthur D. Little, Smith Plant, Panama City, Florida	
Boring No:	9-10
Sample No:	S2
Depth Interval of Sample:	6.5'-8.5'
Depth Interval of Test Specimen:	Remolded (compacted, dense)
Material Description:	Gray/Brown Ash

SPECIMAN DATA:

Dimensions, inches,	
Height:	1.979
Diameter:	2.800
Weight, lbs.,	
Initial:	0.625
Moisture Content, %:	
Initial:	39.2
Final:	39.2
Wet Unit Weight, pcf,	
Initial:	125.4
Final:	125.4
Dry Unit Weight, pcf,	
Initial:	90.1
Back Pressure Saturation, psi,	
Pressures:	10.0
Permeability, cm/sec,	
k:	1.45×10^{-5}

SOIL CLASSIFICATION SHEET



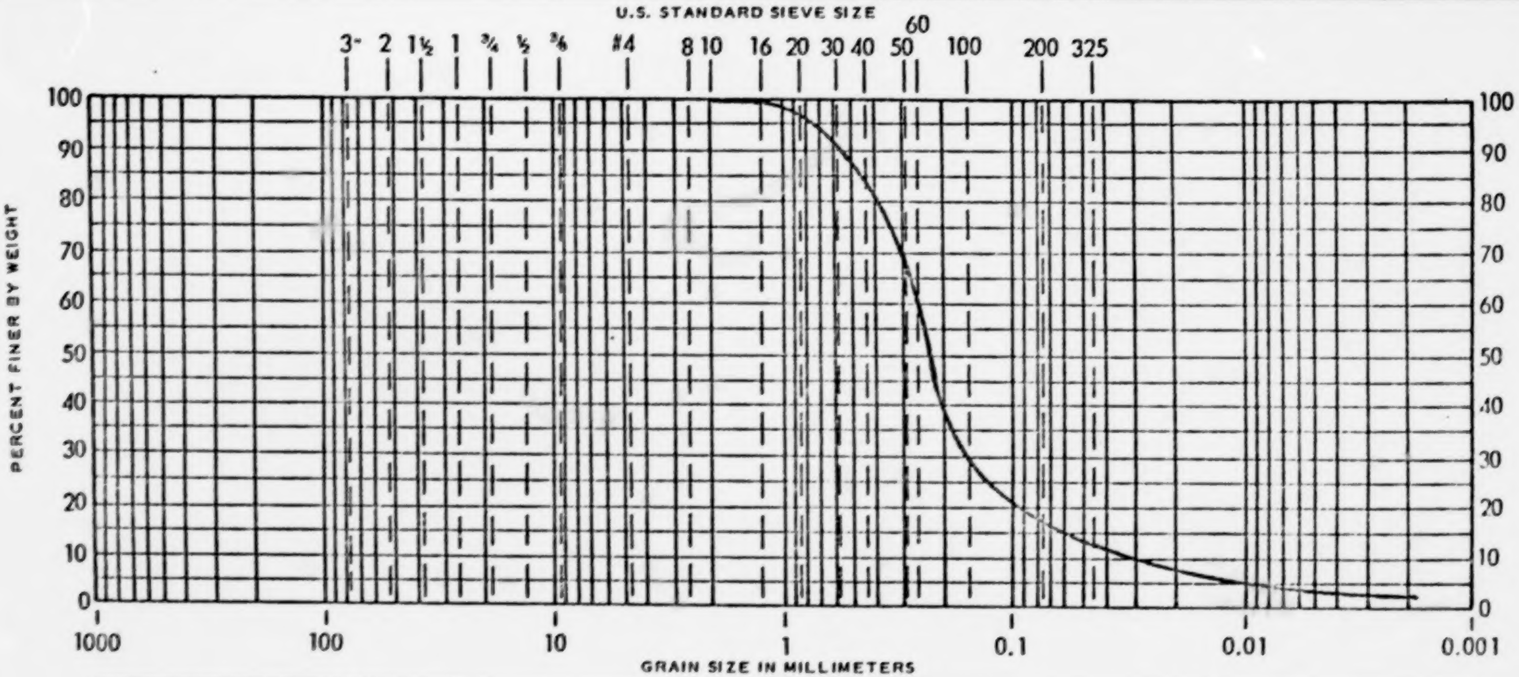
COBBLES	GRAVEL 1%		SAND 35%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	51%	13%

PROJECT Arthur D. Little, Smith Plant, Panama City, Florida
BORING NO. 9-1
SAMPLE NO. S1
DEPTH 0.0'-2.0'
CLASSIFICATION "ML" Sandy "SILT"

NATURAL % MOISTURE Saturated
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



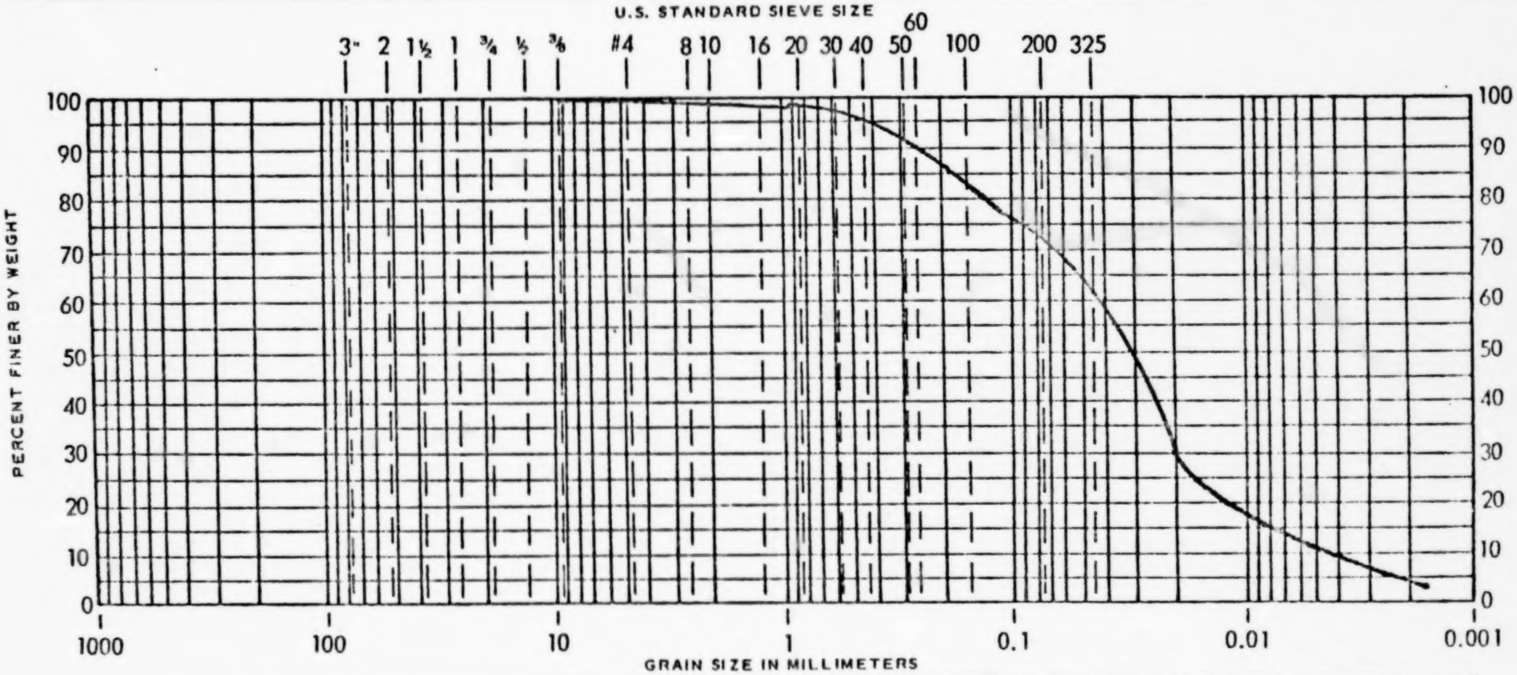
COBBLES	GRAVEL		SAND 83%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	13%	4%

PROJECT Arthur D. Little Smith Plant, Panama City, Florida
BORING NO. 9-1
SAMPLE NO. S3
DEPTH 14.5'-16.5'
CLASSIFICATION "SM" Silty "SAND"

NATURAL % MOISTURE Saturated
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray-Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 27%			SILT 62%	CLAY 10%
	COARSE	FINE	COARSE	MEDIUM	FINE		

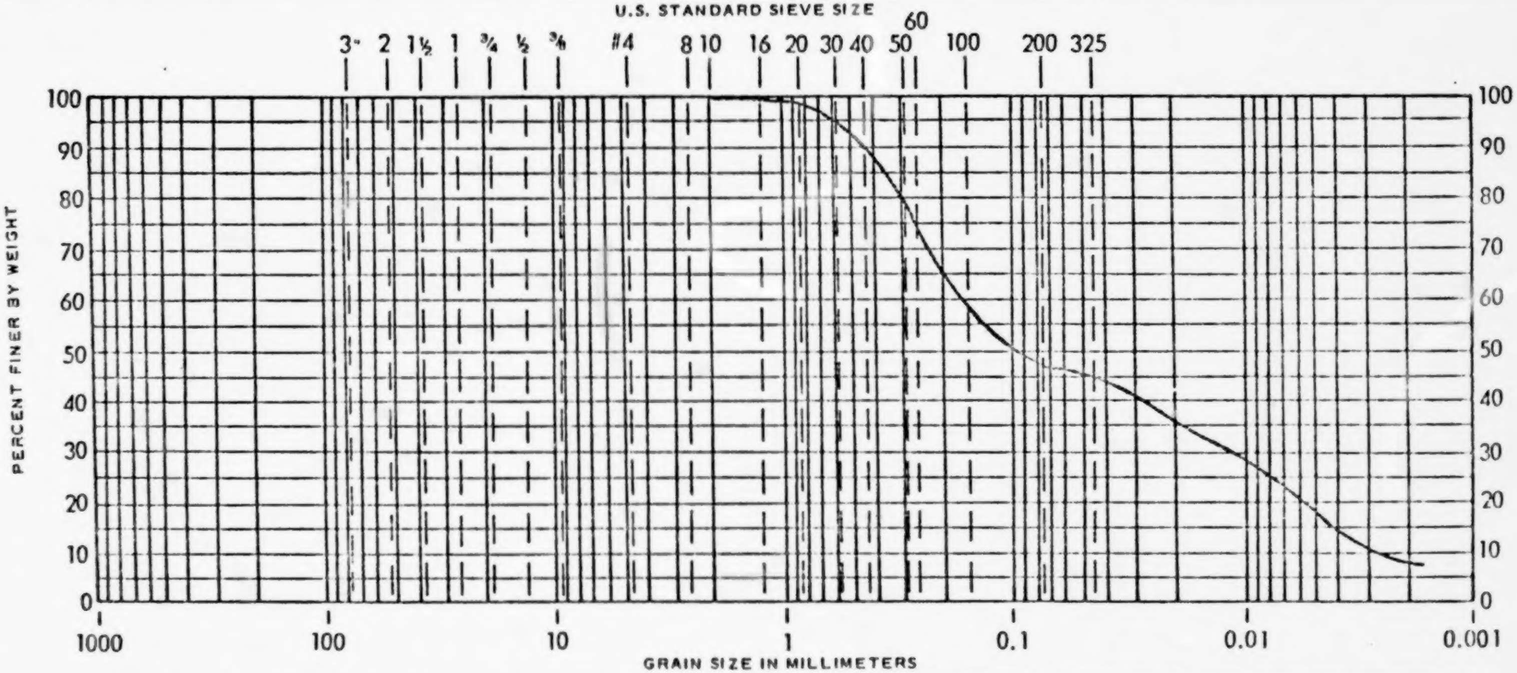
PROJECT Arthur D. Little, Smith Plant, Panama City, Florida
BORING NO. 9-2
SAMPLE NO. S2
DEPTH 4.5'-6.5'
CLASSIFICATION "ML" Sandy "SILT"

NATURAL % MOISTURE Saturated
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL		SAND 53%			SILT 29%	CLAY 18%
	COARSE	FINE	COARSE	MEDIUM	FINE		

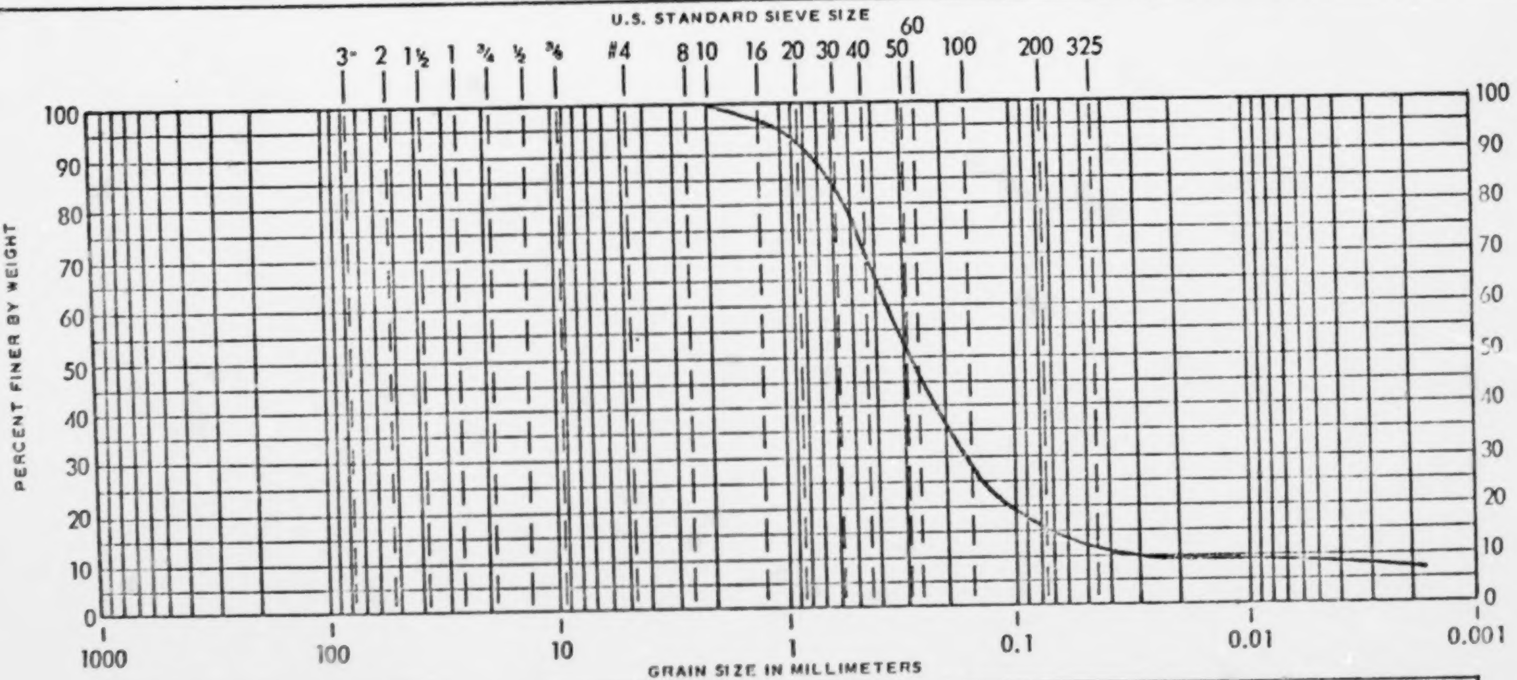
PROJECT Arthur D. Little Smith Plant, Panama City, Florida

BORING NO.	9-2
SAMPLE NO.	S3
DEPTH	9.5'-11.5'
CLASSIFICATION	"SM" Silty "SAND"

NATURAL % MOISTURE	Saturated
LIQUID LIMIT	Tested
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Gray-Brown
REMARKS	"U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL		SAND 84%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	8%	8%

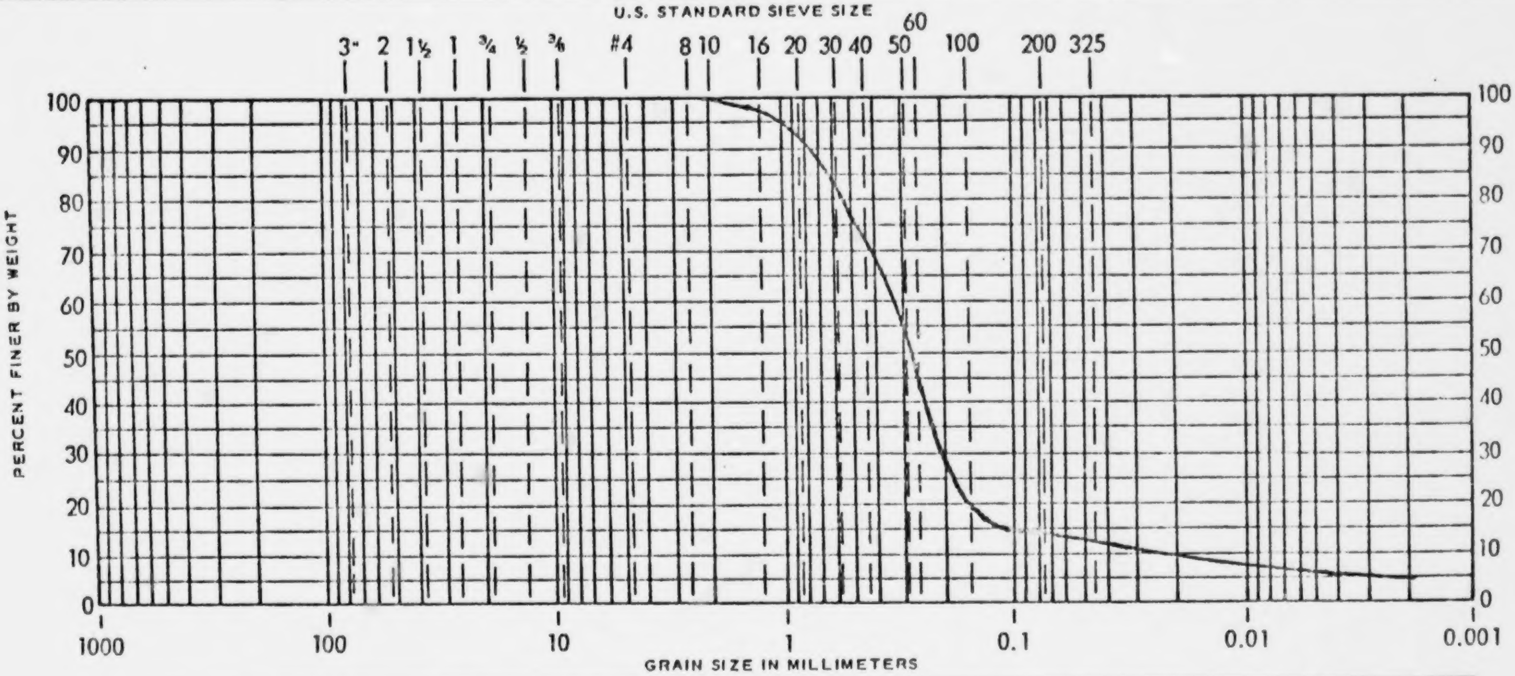
PROJECT Arthur D. Little, Smith Plant, Panama City, Florida
BORING NO. 9-3
SAMPLE NO. T1
DEPTH 9.5'-11.5'
CLASSIFICATION "SM" Silty "SAND"

NATURAL % MOISTURE 33.3
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



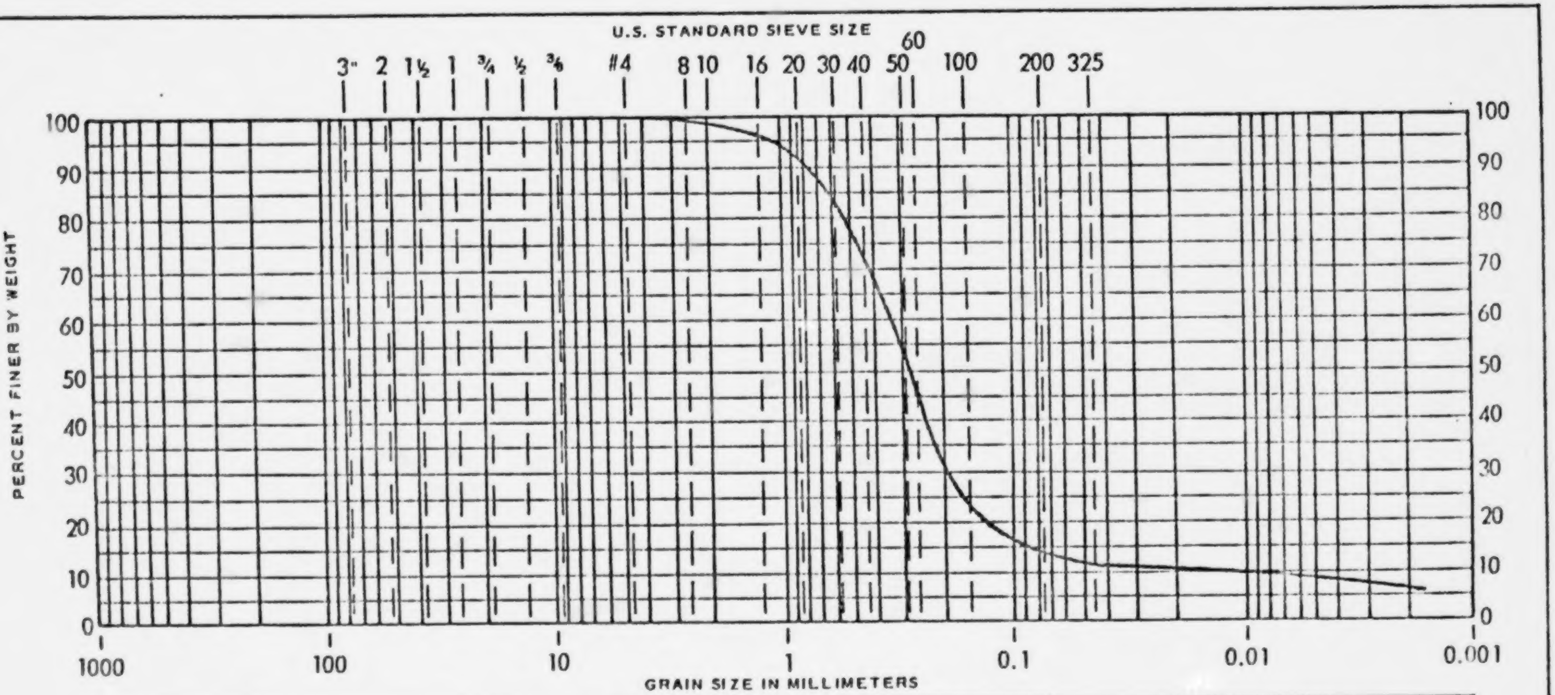
COBBLES	GRAVEL		SAND 86%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	7%	7%

PROJECT Arthur D. Little Smith Plant, Panama City, Florida
BORING NO. 9-5
SAMPLE NO. U1
DEPTH 4.5'-6.5'
CLASSIFICATION "SM"
Silty "SAND"

NATURAL % MOISTURE 8.2
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER .
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL		SAND 87%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	5%	8%

PROJECT Arthur D. Little Smith
Plant, Panama City, Florida
BORING NO. 9-6
SAMPLE NO. U2
DEPTH 4.5'-6.5'
CLASSIFICATION "SM"
Silty "SAND"

NATURAL % MOISTURE 12.3
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No:	9-1
Sample No:	S2
Depth:	6.0'-8.0'

TEST RESULTS

Specific Gravity:	2.21
Material Description:	Gray Fly Ash

SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No: 9-2

Sample No: S1

Depth: 0.0'-2.0'

TEST RESULTS

Specific Gravity: 2.21

Material Description: Gray Fly Ash

SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No:	B9-3
Sample No:	T1
Depth:	9.5'-11.5'

TEST RESULTS

Specific Gravity:	2.65
Material Description:	Brown sand, trace silt

SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No:	9-6
Sample No:	U1
Depth:	4.5'-6.5'

TEST RESULTS

Specific Gravity:	2.72
Material Description:	Brown sand, trace silt

SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Smith Plant, Panama City, Florida

Boring No:	9-6
Sample No:	U2
Depth:	9.5'-11.5'

TEST RESULTS

Specific Gravity:	2.70
Material Description:	Brown sand, trace silt

LABORATORY SUMMARY SHEET

Arthur D. Little, Smith Plant, Panama City, Florida

Page 1 of 4

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classificatio
9-1	S1	0.0-2.0		Tested	Non Plastic		Saturated			"ML"
	S2	6.0-8.0					Saturated			
	S3	14.5-16.5		Tested	Non Plastic		Saturated			"SM"
	S4	19.5-21.5					Saturated			
9-2	S1	0.0-2.0					Saturated			
	S2	4.5-6.5		Tested	Non Plastic		Saturated			"ML"
	S3	9.5-11.5		Tested	Non Plastic		Saturated			"SM"
9-3	S1	0.0-2.0					Saturated			
	S2	4.5-6.5					Saturated			
	S3	11.5-13.5					Saturated			
	S4	14.5-16.5					Saturated			
	S5	19.5-21.5					Saturated			
	S6	24.5-26.5					Saturated			
	S7	29.5-31.5					Saturated			
	S8	35.0-37.0					Saturated			
	S9	39.5-41.5					Saturated			
9-4	S1	0.0-2.0					5.7			
	S2	4.5-6.5					Saturated			
	S3	9.5-11.5					Saturated			
	S4	14.5-16.5					Saturated			
	S5	19.5-21.5					Saturated			
	S6	24.5-26.5					Saturated			
	S7	29.5-31.5					Saturated			
	S8	34.5-36.5					Saturated			
	S9	39.5-41.5					Saturated			

LABORATORY SUMMARY SHEET

Arthur D. Little, Smith Plant, Panama City, Florida

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
9-5	S1	0.0-2.0					13.1			
	S2	6.5-8.5					Saturated			
	S3	9.5-11.5					Saturated			
	S4	14.5-16.5					Saturated			
	S5	16.5-18.5					Saturated			
	S6	19.5-21.5					Saturated			
	S7	24.5-26.5					Saturated			
9-6	S1	0.0-2.0					37.7*			
	S2	3.0-5.0					8.8			
	S3	11.5-13.5					Saturated			
	S4	19.5-21.5					17.5			
9-6A	S1	9.5-11.5					13.2			
9-7	S1	0.0-2.0					Saturated			
	S2	4.5-6.5					Saturated			
	S3	9.5-11.5					Saturated			
	S4	14.5-16.5					Saturated			
	S5	19.5-21.5					Saturated			
	S6	24.5-26.5					28.6			
9-8	S1	0.0-2.0					14.2*			
	S2	6.5-8.5					8.5			
	S3	11.5-13.5					9.5			
	S4	14.5-16.5					Saturated			
	S5	19.5-21.5					14.3			
9-8A	S1	9.5-11.5					6.9			
9-9	S2	4.5-6.5					Saturated			
	S3	9.5-11.5					25.4*			
	S4	14.5-16.5					Saturated			

*140°F

LABORATORY SUMMARY SHEET

Arthur D. Little, Smith Plant, Panama City, Florida

Page 3 of 4

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C. Soil Classi- ficati
9-10	S1	0.0-2.0					---			
	S2	6.5-8.5					21.8*			
	S3	11.5-13.5					5.7*			
	S4	16.5-18.5					16.9			
	S5	18.5-20.5					Saturated			
9-11	S1	0.0-2.0					4.3			
	S2	2.0-2.5					Saturated			
	S3	4.0-6.0					16.4			
	S4	6.0-8.0					---			
	S5	10.0-11.0					Saturated			
	S6	15.0-16.5					Saturated			
	S7	19.5-20.5					20.6*			
	S8	24.5-26.5					Saturated			
	S9	29.5-31.5					18.4*			
	S10	34.5-36.5					Saturated			
	S11	44.5-46.5					Saturated			
	S12	54.5-56.5					Saturated			
	S13	69.5-71.5					Saturated			
	S14	83.5-85.5					27.7*			
	S15	98.5-99.5					Saturated			
9-11A	S1	9.5-11.5					Saturated			
9-12	S1	0.0-2.0					24.9			
	S2	5.0-7.0					Saturated			
	S3	10.0-12.0					Saturated			
	S4	15.0-17.0					25.1*			
	S5	20.0-22.0					Saturated			
	S6	24.0-26.0					Saturated			

*140°F

LABORATORY SUMMARY SHEET

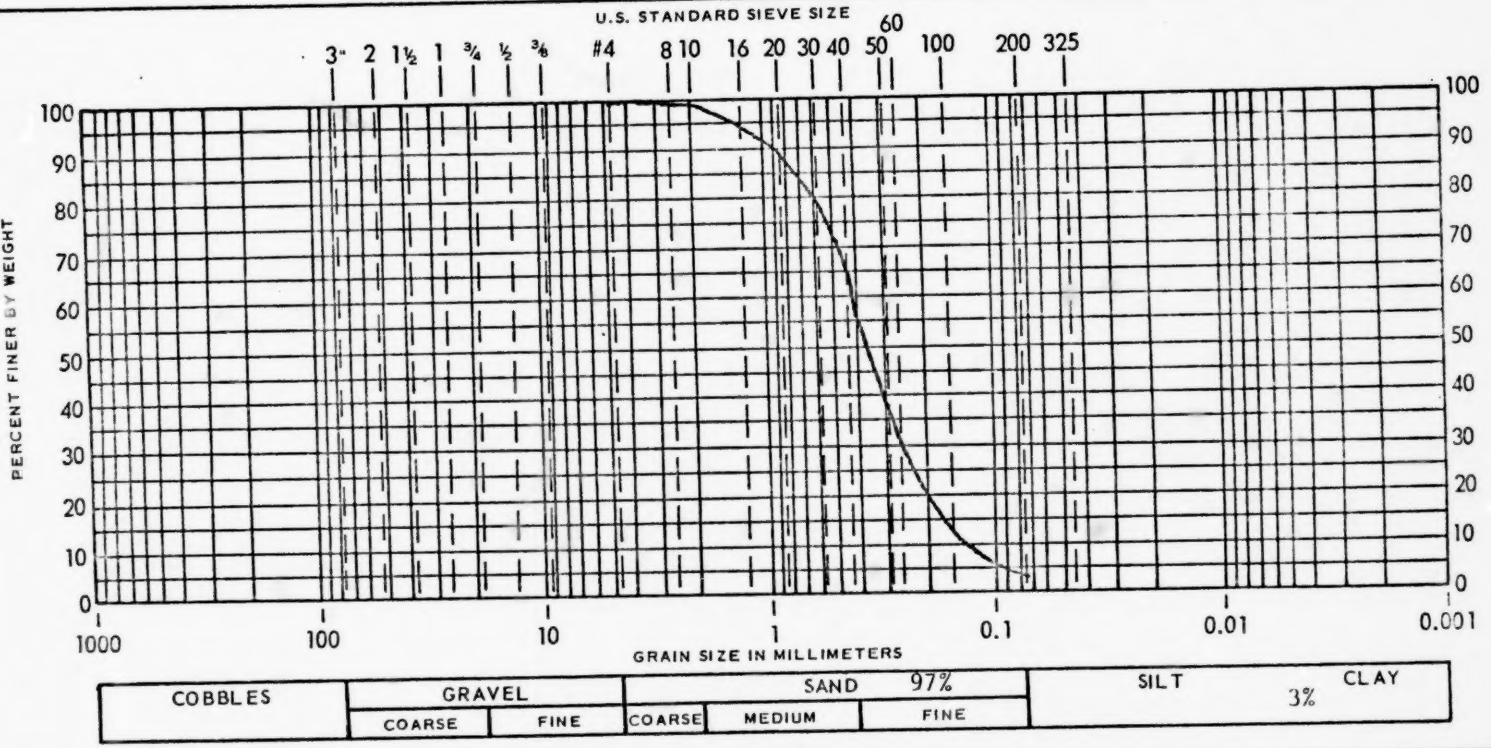
Arthur D. Little, Smith Plant, Panama City, Florida

Page 4 of 4

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plas-ticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S Soil Classi-ficatio
9-13	S1	0.0-2.0					25.0			
	S2	2.0-4.0					17.1			
	S3	4.0-6.0					29.5			
	S4	9.5-11.5					Saturated			
	S5	14.5-16.5					Saturated			
	S6	19.5-21.5					28.4*			
	S7	24.5-26.5					Saturated			
	S8	29.5-31.5					Saturated			
9-14	S1	0.0-2.0					17.0*			
	S2	4.0-6.0					18.0			
	S3	6.0-8.0					9.6			
	S4	9.5-11.5					14.0			
	S5	14.5-16.5					Saturated			
9-1	T1	9.0-11.0					---			
9-3	T1	9.5-11.5	Permeability	Tested	Non Plastic		33.3	98.0		"SM
9-5	U1	4.5-6.5	Permeability	Tested	Non Plastic		8.4	93.1		"SM
9-6	U1	4.5-4.7	Permeability				63.3*	47.7		
	U1	5.5-5.7	Permeability				6.5*	94.6		
	U2	9.5-11.5	Permeability	Tested	Non Plastic		12.3*	97.5		"SM
9-8	U1	4.5-6.5								
	U2	9.5-11.5	Permeability				13.7	103.2		
9-10	U1	4.5-6.5								
	U2	9.5-11.5	Permeabilty				12.7	103.0		
	U3	14.5-16.5								

*140°F

SOIL CLASSIFICATION SHEET



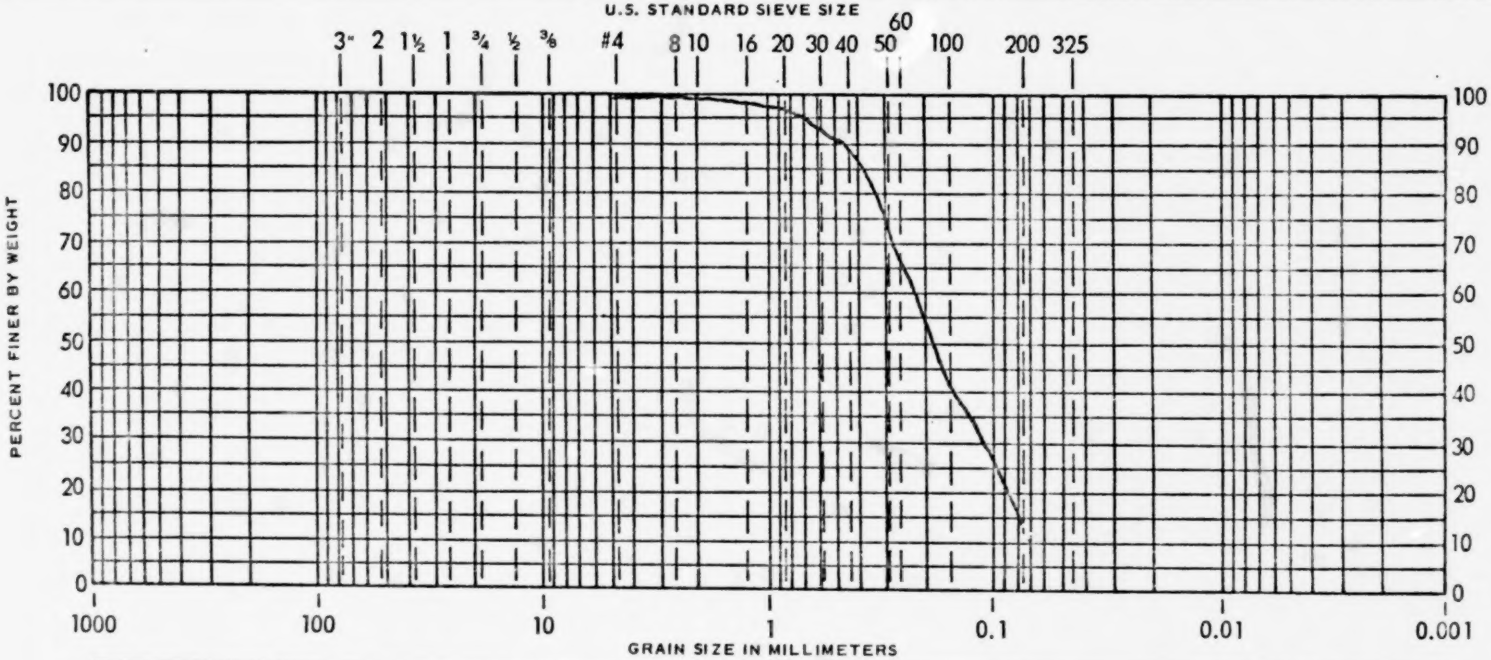
PROJECT Smith Power Plant,
A.D.L.
BORING NO. 9-3
SAMPLE NO. S-3
DEPTH 11.5'-13.5'
CLASSIFICATION "SP"
Poorly graded "SAND"

NATURAL % MOISTURE Saturated
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Grayish-Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



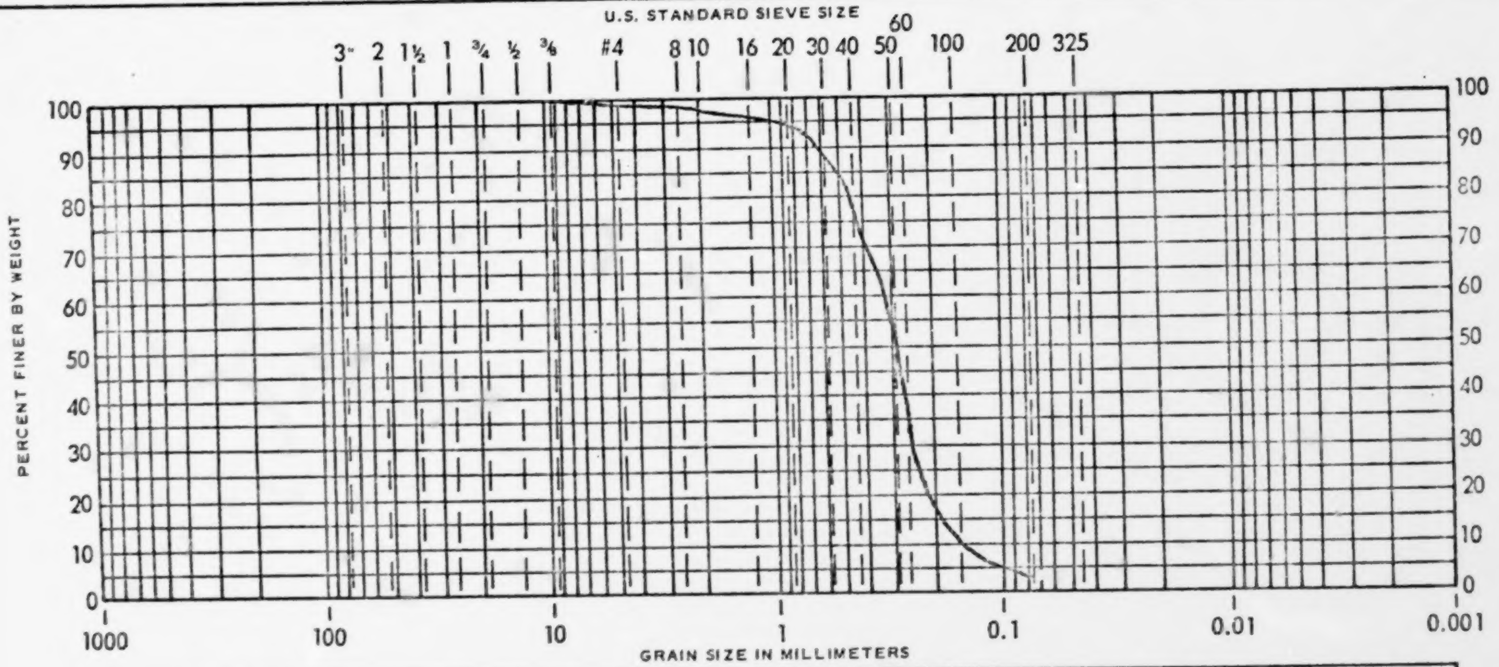
COBBLES	GRAVEL 0%		SAND 87%			SILT 13% CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

PROJECT Smith Power Plant, A.D.L.
BORING NO. 9-4
SAMPLE NO. S5
DEPTH 19.5'-21.5'
CLASSIFICATION "SM" Silty "SAND"

NATURAL % MOISTURE 22.8
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



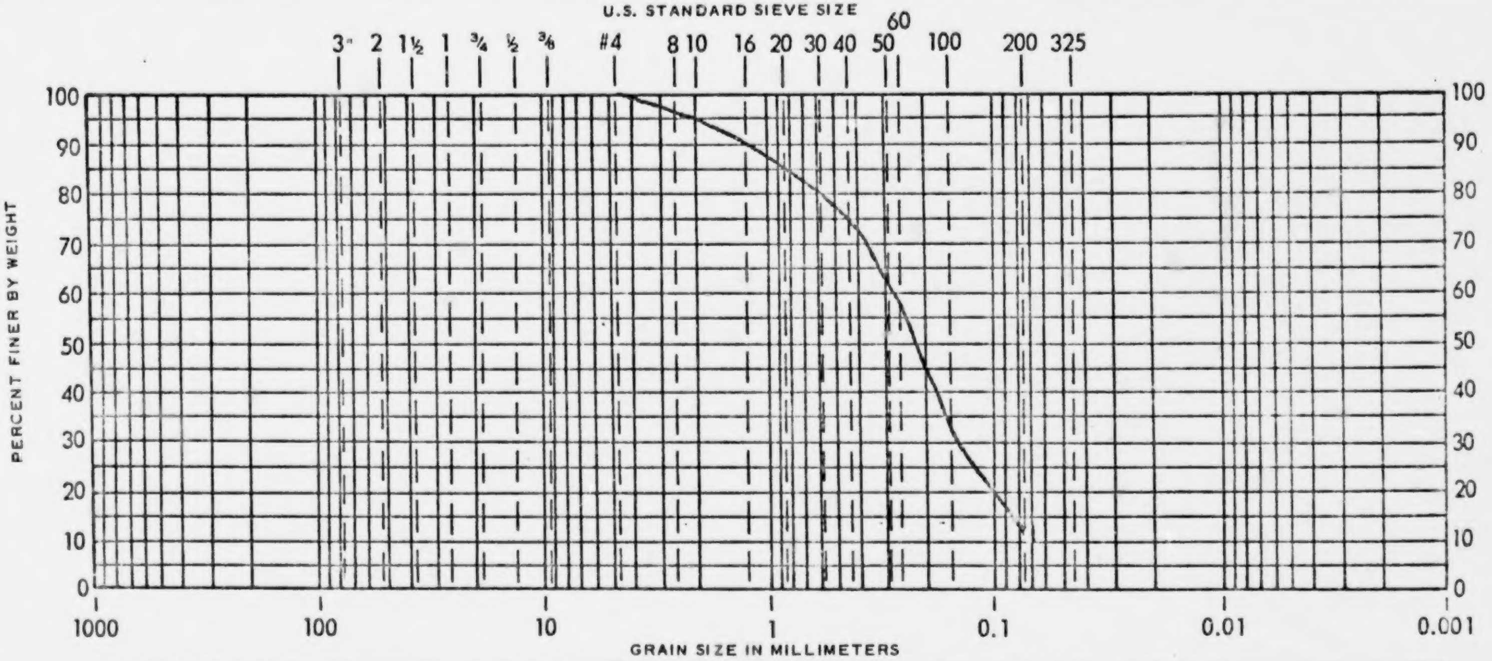
COBBLES	GRAVEL 1%		SAND 96%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	3%	

PROJECT	Smith Power Plant, A.D.L.
BORING NO.	9-9
SAMPLE NO.	S-3
DEPTH	9.5'-11.5'
CLASSIFICATION	"SP" Poorly graded "SAND"

NATURAL % MOISTURE	Saturated
LIQUID LIMIT	Visually
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Brown
REMARKS	"U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



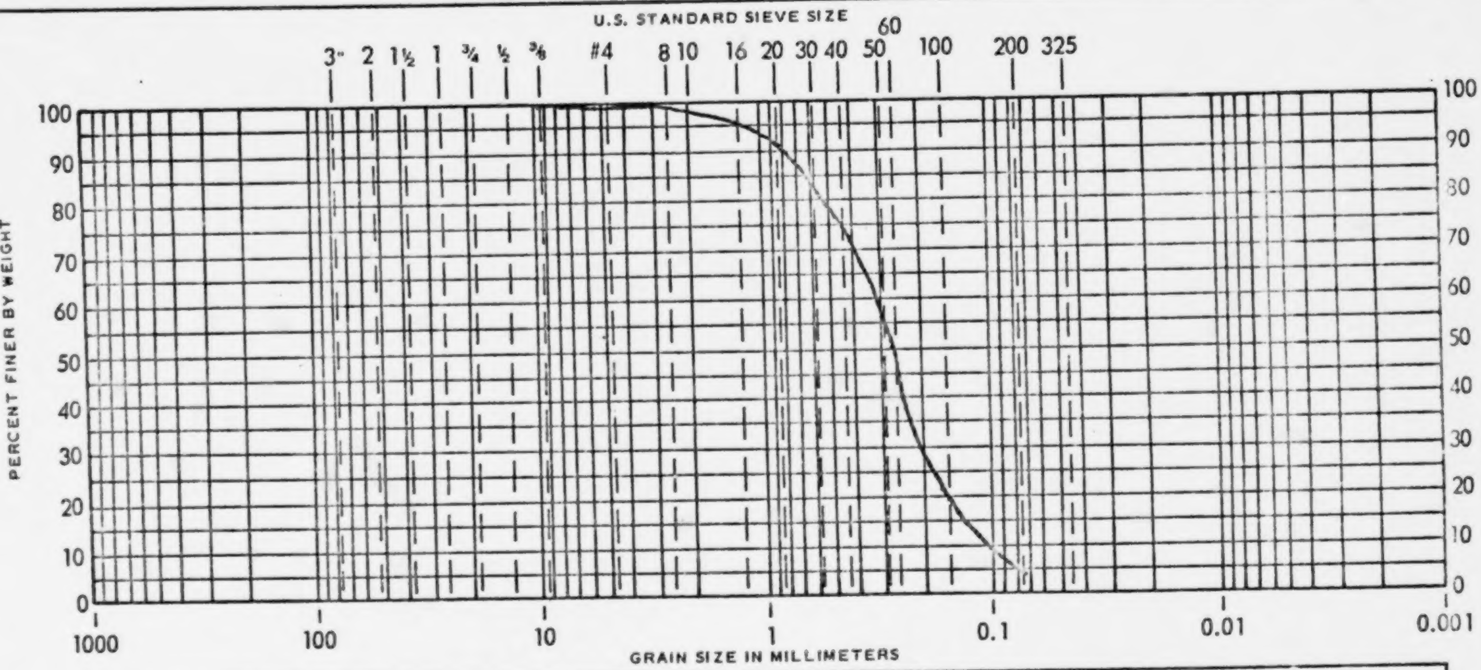
COBBLES	GRAVEL 0%		SAND 88%			SILT CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	12%

PROJECT Smith Power Plant, A.D.L.
BORING NO. 9-5
SAMPLE NO. S5
DEPTH 16.5'-18.5'
CLASSIFICATION "SM" Silty "SAND"

NATURAL % MOISTURE 20.4
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 94%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	5%	

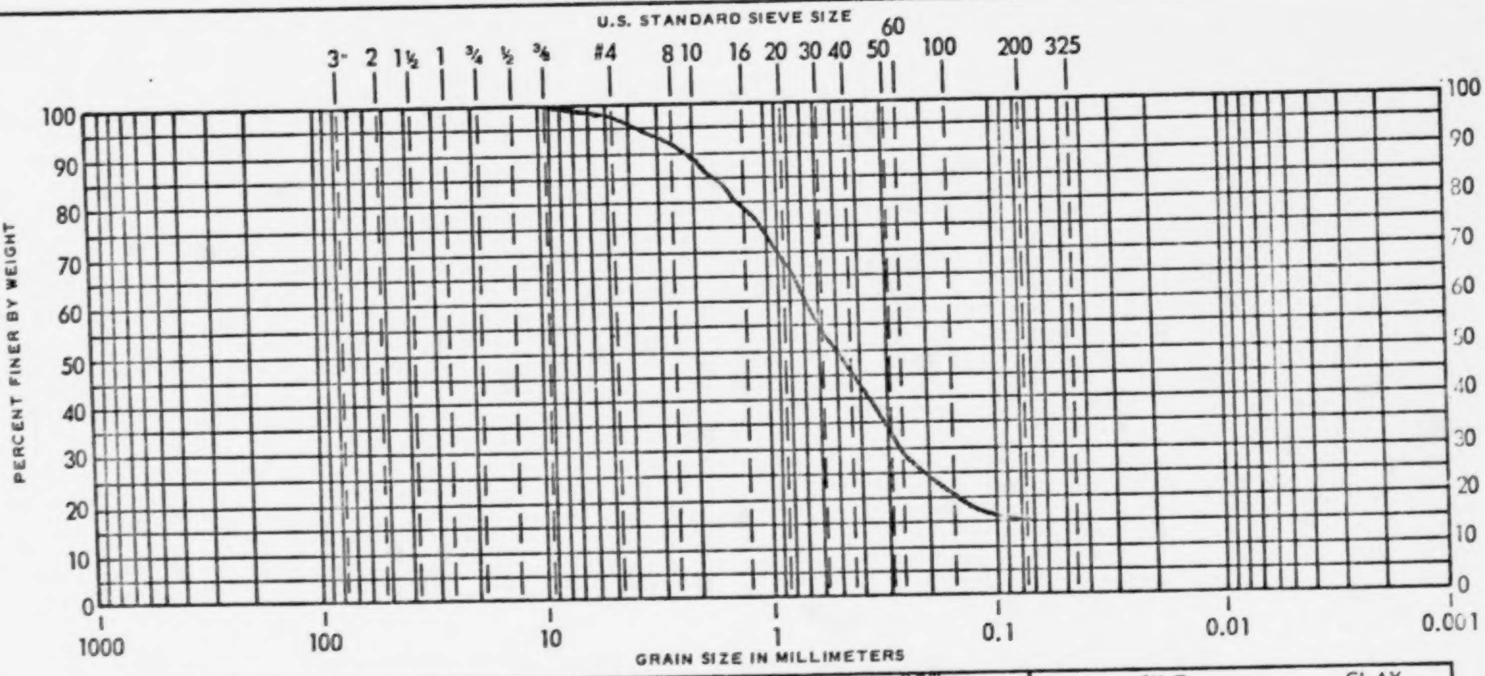
PROJECT Smith Power Plant,
A.D.L.
BORING NO. 9-11
SAMPLE NO. S-5
DEPTH 10.0'-11.0'
CLASSIFICATION "SP-SM"
Poorly Graded·Silty "SAND"

NATURAL % MOISTURE Saturated
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Grayish-Black
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 2%		SAND 82%			SILT 16% CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

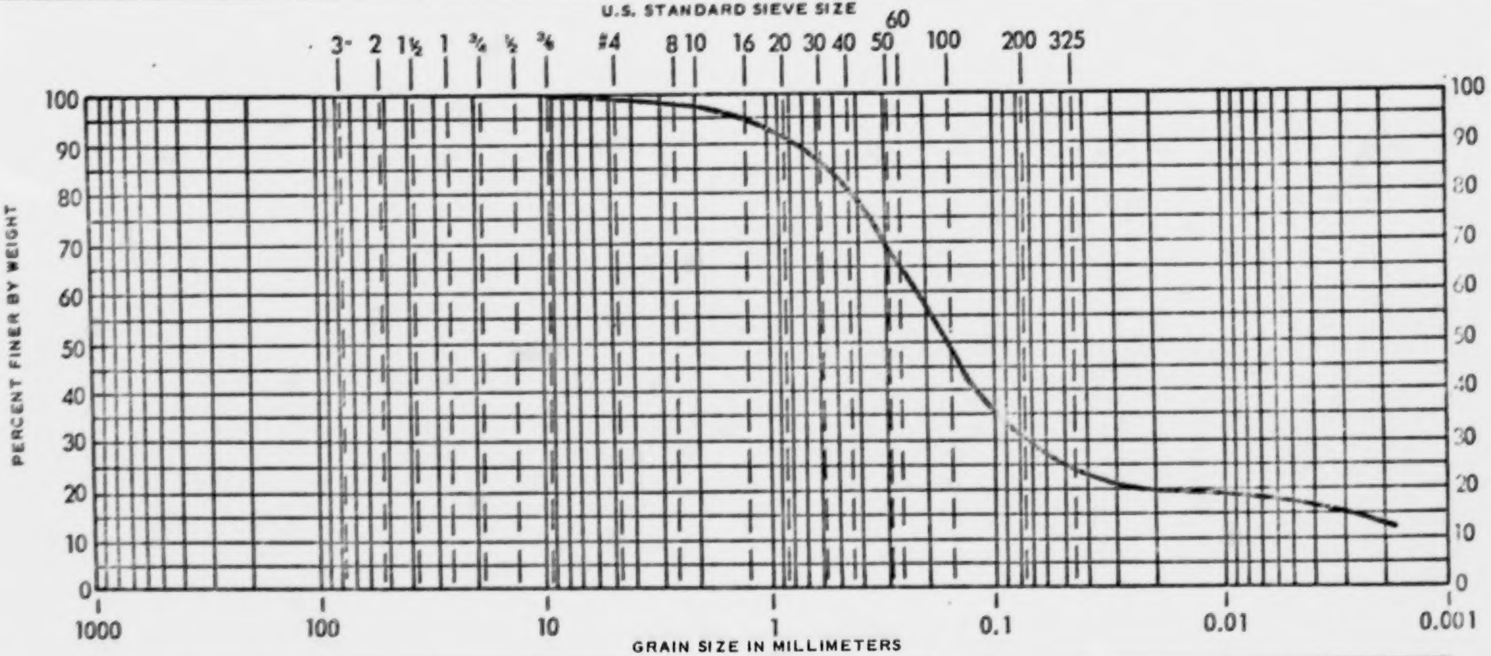
PROJECT Smith Power Plant, A.D.L.
BORING NO. 9-12
SAMPLE NO. S-4
DEPTH 15.0'-17.0'
CLASSIFICATION "SM" Silty "SAND"

NATURAL % MOISTURE Saturated
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Black
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



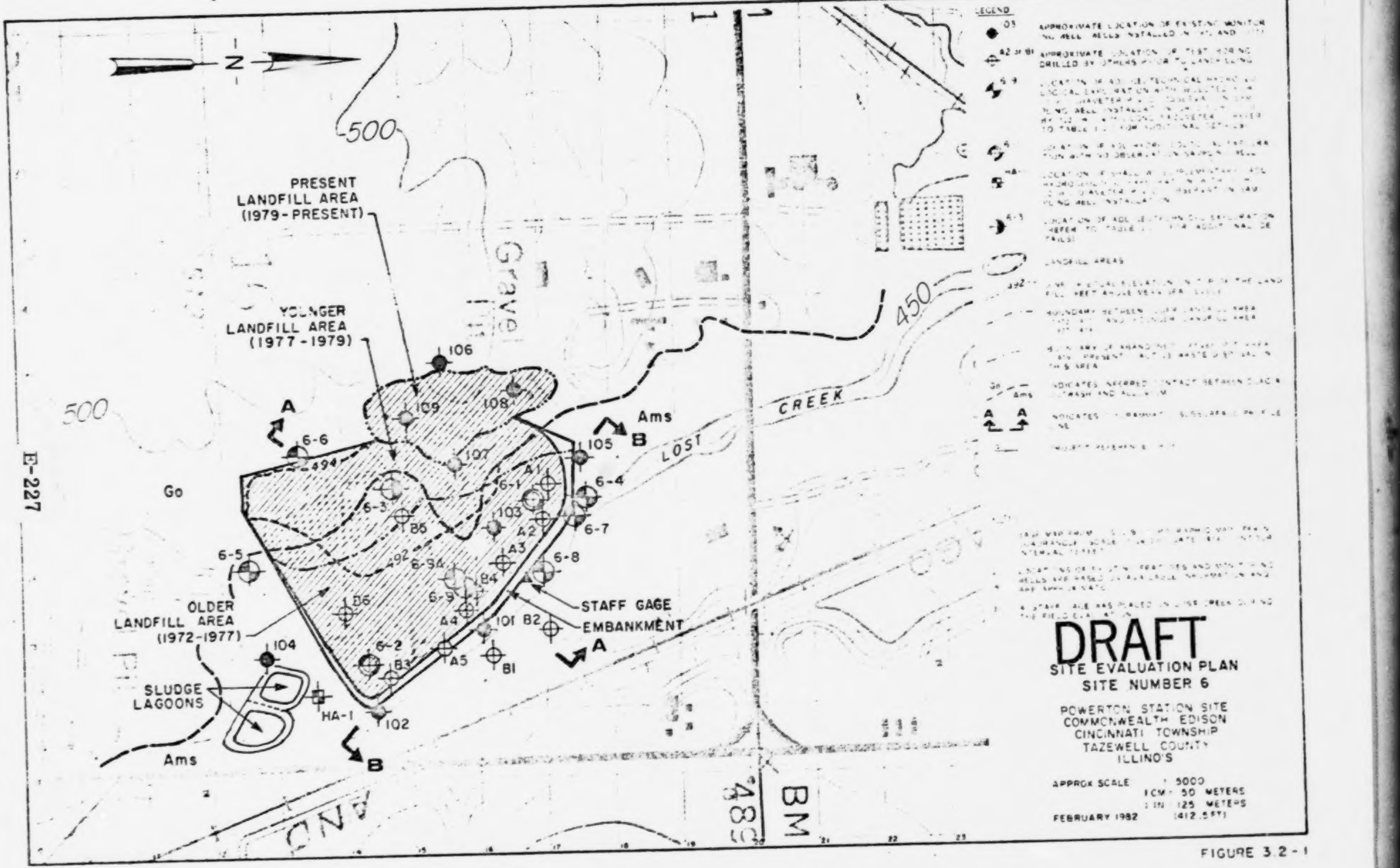
COBBLES	GRAVEL 1%		SAND 71%			SILT 8%	CLAY 20%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT	Smith Power Plant, A.D.L.
BORING NO.	9-13
SAMPLE NO.	S6
DEPTH	19.5'-21.5'
CLASSIFICATION	"SM" Silty "SAND"

NATURAL % MOISTURE	27.8
LIQUID LIMIT	Tested
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Gray & Brown
REMARKS	"U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

Powerton Commonwealth Edison


N
500
450
Gravel Pit
1
BM
489
PRESENT LANDFILL AREA (1979-PRESENT)
YOUNGER LANDFILL AREA (1977-1979)
OLDER LANDFILL AREA (1972-1977)
SLUDGE LAGOONS
STAFF GAGE
EMBANKMENT
LOST CREEK
AND
Go
Ams
A
B
106
108
109
107
105
6-6
494
6-4
6-7
A1
6-1
103
A2
A3
6-8
6-3
B5
492
6-5A
B4
6-9
A4
101
B2
B6
6-2
B3
A5
B1
6-5
104
HA-1
102
LEGEND
APPROXIMATE LOCATION OF EXISTING MONITORING WELL
APPROXIMATE LOCATION OF TEST BORING DRILLED BY OTHERS PRIOR TO LANDFILLING
LANDFILL AREAS
INDICATES INFERRED CONTACT BETWEEN GLACIAL OUTWASH AND ALLUVIUM

DRAFT
SITE EVALUATION PLAN
SITE NUMBER 6

POWERTON STATION SITE
COMMONWEALTH EDISON
CINCINNATI TOWNSHIP
TAZEWELL COUNTY
ILLINOIS

APPROX SCALE 1 : 5000
1CM = 50 METERS
1 IN = 125 METERS
(412.5FT)

FEBRUARY 1982

FIGURE 3.2-1

Reproduced from best available copy.

SUMMARY OF RESULTS

QA/QC PHYSICAL PROPERTY TESTS

POWERTON SITE

Boring No.: 6-1

Sample No.: T1

Depth: 4.0' - 6.0'

Date of sampling: November 20, 1981

Results of permeability tests on remolded compacted samples

Depth Interval (ft.)	Material	Water Content (%)	Moist Density (pcf)	Dry Density (pcf)	Coefficient of Permeability (cm/sec)
4.0-4.5	bottom ash	5.10			
4.5-5.0	bottom ash	2.47	75.0	73.2	3.40×10^{-2}
5.0-5.5	bottom ash	7.22			
5.5-6.0	bottom ash	3.15			

Extended Permeability Test

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No.	6-2
Sample No:	U1
Depth Interval of Sample:	4.0'-6.0'
Depth Interval of Test Specimen:	5.0'-5.5'

SPECIMEN DATA

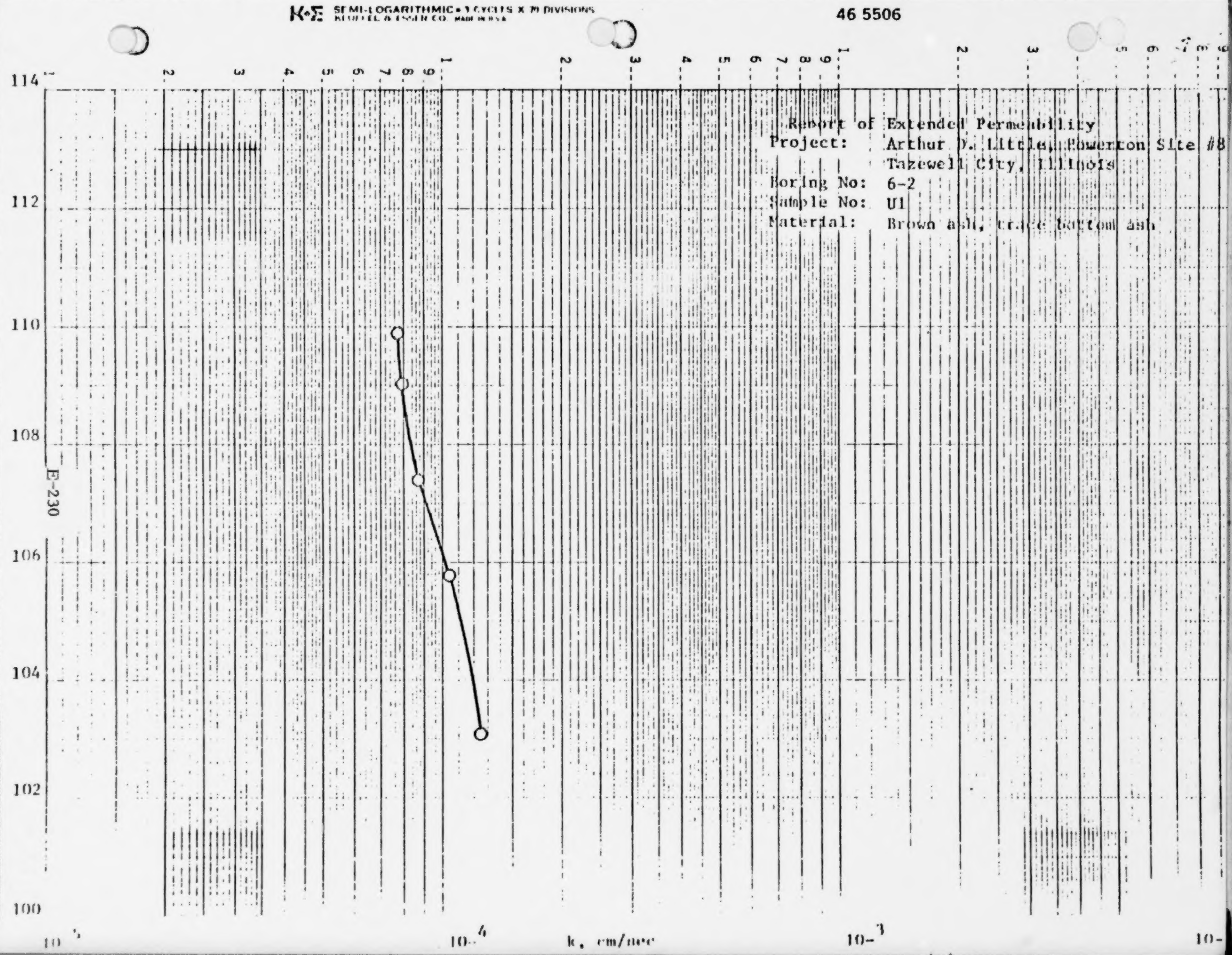
Initial Conditions,

Height:	5.932"
Diameter:	2.871"
Weight:	2.58 lbs
Moisture Content:	12.8%
Specific Gravity:	2.63
Wet Unit Weight:	116.3 pcf
Dry Unit Weight:	103.1 pcf

Test Summary

Graphical Presentation on Following Pages

Dry Unit Weight pcf	Permeability, k 10 - 4 cm/sec
103.1	1.25
105.8	1.05
107.4	0.87
109.2	0.80
109.9	0.77



Report of Extended Permeability
Project: Arthur D. Little, Powerton Site #8
Tazewell City, Illinois
Boring No: 6-2
Sample No: U1
Material: Brown ash, trace bottom ash

Constant Head
Permeability Test
Laboratory Compacted

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No: 6-2

Sample No: U2

Depth Interval of Sample: Bag Sample (loose, remolded)

Material Description: Gray Brown Ash

SPECIMEN DATA:

Dimensions, inches,

Height: 4.505
Diameter: 4.002

Weight, lbs.,

Initial: 2.28

Moisture Content, %:

Initial: 20.8
Final: 48.2

Wet Unit Weight, pcf,

Initial 69.5
Final: 85.2

Dry Unit Weight, pcf,

Initial 57.5

Back Pressure Saturation, psi,

Pressures: 5.0

Permeability, cm/sec,

k: 1.61×10^{-5}

Constant Head Permeability Test Laboratory Compacted

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No: 6-2

Sample No: U2

Depth Interval of Sample: 14.0'-16.0'

Depth Interval of Test Specimen: Remolded (compacted)

Material Description: Gray/Brown Ash

SPECIMEN DATA:

Compaction Data,

Undisturbed Conditions
  Dry Unit Weight, pcf: ---
  Moisture Content, %: ---

Dimensions, inches,

  Height:
  Diameter: 2.654
  2.697

Weight, lbs.,

  Initial: 1.06

Moisture Content, %:

  Initial: 15.6
  Final: 19.4

Wet Unit Weight, pcf,

  Initial 120.8
  Final: 124.8

Dry Unit Weight, pcf,

  Initial 104.5

Back Pressure Saturation, psi,

  Pressures: 20.0

Permeability, cm/sec,

  k: 5.3×10^{-6} E-232

Constant Head
Permeability Test
Laboratory Compacted

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No: 6-3

Sample No: T1

Depth Interval of Sample: Bag Sample (loose, remolded)

Material Description: Gray/Brown Bottom Ash

SPECIMEN DATA:

Dimensions, inches,

Height: 2.000
Diameter: 2.851

Weight, lbs.,

Initial 0.624

Moisture Content, %:

Initial: 2.2
Final: 38.9

Wet Unit Weight, pcf,

Initial: 84.4
Final: 114.7

Dry Unit Weight, pcf,

Initial: 82.6

Back Pressure Saturation, psi,

Pressures: 10.0

Permeability, cm/sec,

k: 5.56×10^{-5}

Constant Head
Permeability Test
Laboratory Compacted

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No:	6-3
Sample No:	T1
Depth Interval of Sample:	Bag Sample (dense, remolded)
Material Description:	Gray/Brown Bottom Ash

SPECIMEN DATA:

Dimensions, inches,	
Height:	1.982
Diameter:	2.825
Weight, lbs.,	
Initial	0.743
Moisture Content, %:	
Initial:	21.8
Final:	21.8
Wet Unit Weight, pcf,	
Initial:	
Final:	103.3
Dry Unit Weight, pcf,	
Initial:	84.8
Back Pressure Saturation, psi,	
Pressures:	10.0
Permeability, cm/sec,	
k:	3.95×10^{-5}

Constant Head
Permeability Test

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No: 6-1

Sample No: T2

Depth Interval of Sample: 22.0'-24.0'

Depth Interval of Test Specimen: 22.0'-22.3'

Material Description: Gray Bottom Ash

SPECIMEN DATA:

Dimensions, inches,

Height: 3.418
Diameter: 1.780

Weight, lbs.,

Initial: 0.51

Moisture Content, %:

Initial: 8.1
Final: 14.9

Wet Unit Weight, pcf,

Initial 102.7
Final: 109.1

Dry Unit Weight, pcf,

Initial 95.0

Back Pressure Saturation, psi,

Pressures: 10.0

Permeability, cm/sec,

k: 2.5×10^{-4}

Constant Head
Permeability Test

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No: 6-2

Sample No: T1

Depth Interval of Sample: 27.0'-29.0'

Material Description: Brown sand some silt

SPECIMEN DATA:

Dimensions, inches,

Height: 2.000
Diameter: 1.904

Weight, lbs.,

Initial: 0.38

Moisture Content, %:

Initial: 17.2
Final: 20.7

Wet Unit Weight, pcf,

Initial 114.2
Final: 117.6

Dry Unit Weight, pcf,

Initial 97.5

Back Pressure Saturation, psi,

Pressures: 30.0

Permeability, cm/sec,

k: 6.1×10^{-6}

Constant Head
Permeability Test

Project:	Arthur D. Little, Powerton Site #8, Tazewell City, Illinois
Boring No:	6-2
Sample No:	T2
Depth Interval of Sample:	29.0'-31.0'
Depth Interval of Test Specimen:	29.0'-29.2'
Material Description:	Brown clay liner with ash

SPECIMEN DATA:

Dimensions, inches,	
Height:	2.000
Diameter:	1.866
Weight, lbs.,	
Initial:	0.44
Moisture Content, %:	
Initial:	12.3
Final:	12.5
Wet Unit Weight, pcf,	
Initial	139.1
Final:	139.4
Dry Unit Weight, pcf,	
Initial	123.9
Back Pressure Saturation, psi,	
Pressures:	10.0
Permeability, cm/sec,	
k:	2.4×10^{-6}

Constant Head
Permeability Test

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No: 6-3

Sample No: T1

Depth Interval of Sample: 4.0'-6.0'

Depth Interval of Test Specimen: 4.0'-4.2'

Material Description: Gray Bottom Ash

SPECIMEN DATA:

Dimensions, inches,

  Height: 3.421
  Diameter: 1.773

Weight, lbs.,

  Initial: 0.46

Moisture Content, %:

  Initial: 3.1
  Final: 20.2

Wet Unit Weight, pcf,

  Initial 93.3
  Final: 108.8

Dry Unit Weight, pcf,

  Initial 90.5

Back Pressure Saturation, psi,

  Pressures: 10.0

Permeability, cm/sec,

  k: 5.3×10^{-4}

Test No. 1

CONSOLIDATED-UNDRAINED TRIAXIAL TEST SUMMARY

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

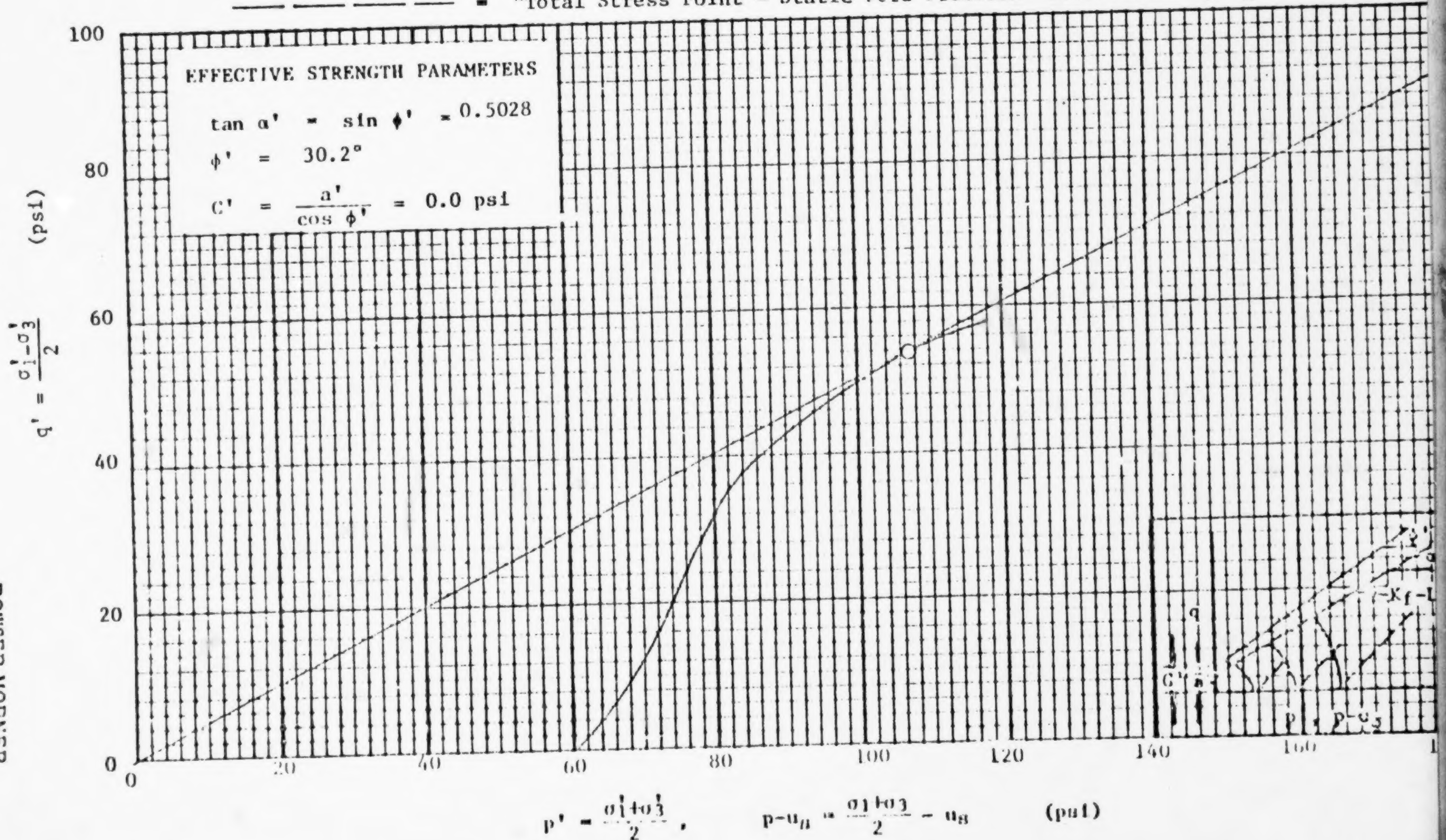
SAMPLE CONDITIONS	Test Sample 1
Sample Preparation:	Undisturbed
Material:	Gray/Brown Ash
Boring No.:	6-2
Sample No.:	U1
Depth (ft):	5.0'-5.5'
Effective Consolidation Pressure (psi):	60.0
Saturation Pressures, Initial Conditions,	
Lateral (psi):	15.0
Back (psi):	10.0
Consolidation Pressures, Initial Shearing Conditions,	
Lateral (psi):	90.0
Back (psi):	30.0
Initial Conditions,	
Height (inches):	5.932
Diameter (inches):	2.871
Weight (lbs.):	2.58
Moisture Content (%):	12.8
Volume (cf):	.02222
Dry Unit Weight (pcf):	103.1
Wet Unit Weight (pcf):	116.3
Consolidated conditions,	
Moisture Content (%):	19.8
Volume (cf):	.02080
Dry Unit Weight (pcf):	109.9
Wet Unit Weight (pcf):	131.7
At Maximum Principal Effective Stress Ratio,	
$p' = (\sigma_1 + \sigma_3)/2$ (psi):	107.3
$q' = (\sigma_1 - \sigma_3)/2$ (psi):	54.2
Measured Strength Parameters:	
Effective ϕ' (°) =	30.2
C'(psi) =	0.0

CONSOLIDATED-UNDRAINED TRIAXIAL STRESS PATHS

TEST NO. 1

Project: ARTHUR D. LITTLE, POWERTON SITE #8, TAZEWELL CITY, ILL.
Material: Gray and Brown Ash

○ = Maximum Principal Effective Stress Ratio
——— = Effective Stress Path (p' vs. q)
— — — — = "Total Stress Point - Static Pore Pressure" Stress Path ($p-u_s$ vs. q)



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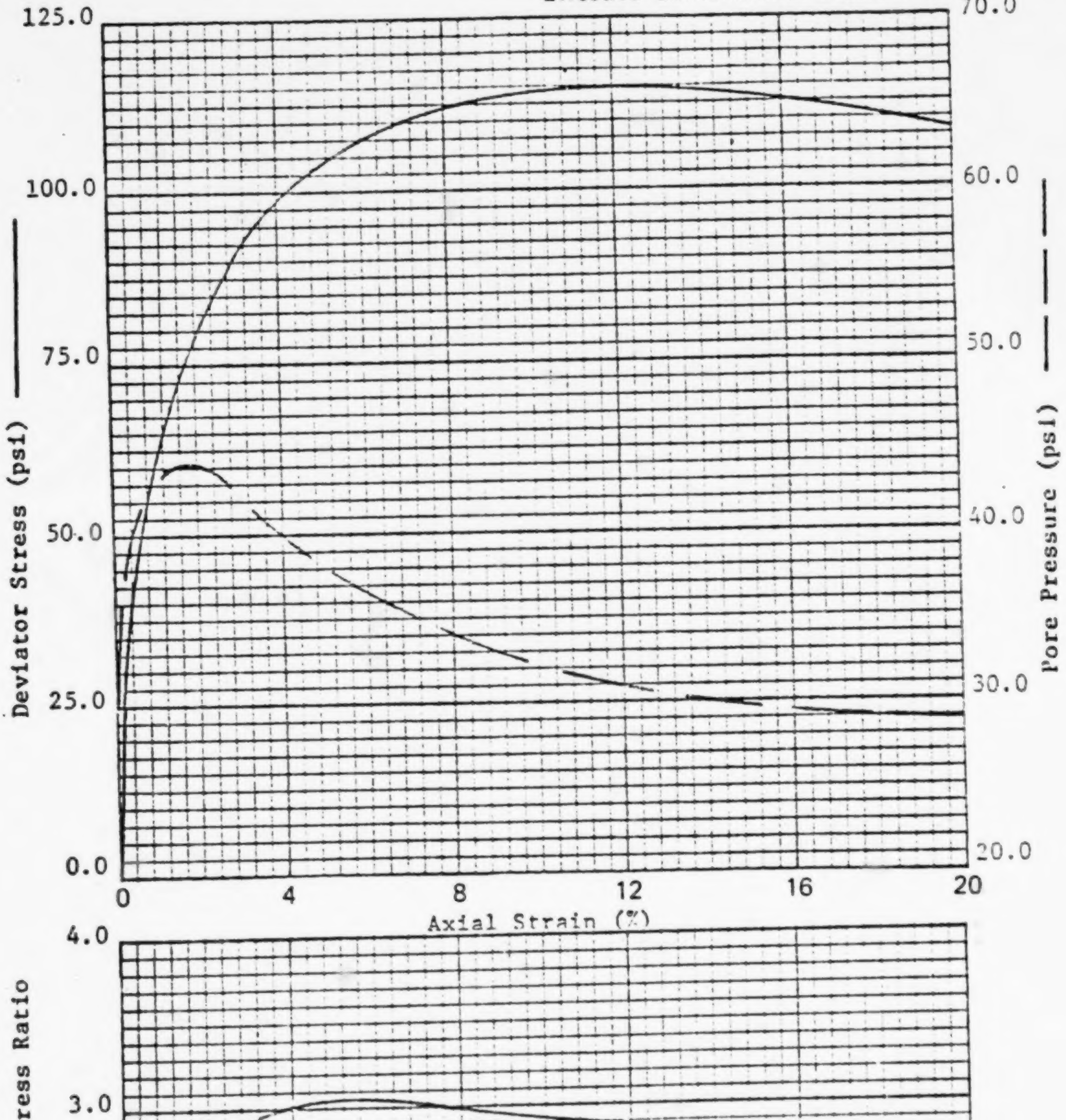
Testing Laboratories, Inc.

2A99

TEST NO. 1
SAMPLE NO. 1

ARTHUR D. LITTLE, POWERTON SITE #8, TAZEWELL CITY, ILL.

Initial Pore Pressure Reading (psi): 30.0
Effective Consolidation Pressure (psi): 60.0



Specific Gravity of Soils

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No: 6-1

Sample No: T2

Depth: 22.0'-24.0'

TEST RESULTS

Specific Gravity: 2.73

Material Description: Gray Bottom Ash

SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No:	6-1
Sample No:	S 10
Depth:	34.0'-36.0'

TEST RESULTS:

Specific Gravity:	2.79
Material Description:	Gray Fly Ash

SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No:	6-2
Samle No:	U1
Depth, ft:	4.0'-6.0'

TEST RESULTS

Specific Gravity:	2.63
Material Description:	Gray/Brown Ash

SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No: 6-2

Sample No: U2

Depth: 14.0'-16.0'

TEST RESULTS:

Specific Gravity: 2.64

Material Description: Gray Ash

SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No: 6-2

Sample No: T1

Depth: 27.0'-29.0'

TEST RESULTS:

Specific Gravity: 2.72

Material Description: Black Bottom Ash

SPECIFIC GRAVITY OF SOILS

Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No: 6-2

Sample No: T2

Depth: 29.0'-31.0'

TEST RESULTS:

Specific Gravity: 2.67

Material Description: Brown clay liner with ash

SPECIFIC GRAVITY OF SOILS

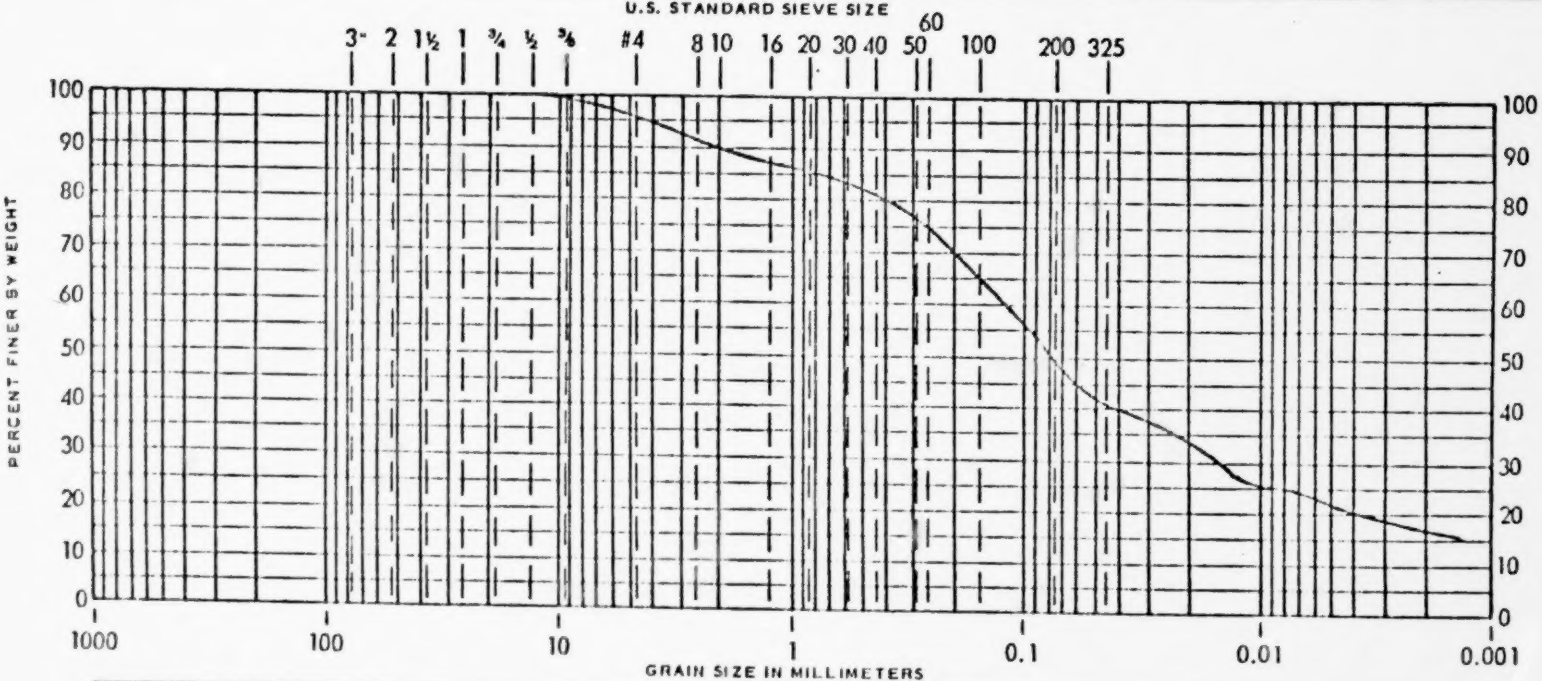
Project: Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Boring No:	6-3
Sample No:	T1
Depth, ft:	4.0'-6.0'

TEST RESULTS:

Specific Gravity:	2.75
Material Description:	Bottom Ash

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 5%		SAND 46%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	26%	23%

PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill

BORING NO.	6-1
SAMPLE NO.	S1
DEPTH	0.0'-2.0'
CLASSIFICATION	"SC" Clayey "SAND"
NATURAL % MOISTURE	11.7
LIQUID LIMIT	30
PLASTIC LIMIT	17
PLASTICITY INDEX	13
COLOR	Reddish-Brown
REMARKS	"U.S.C.S."

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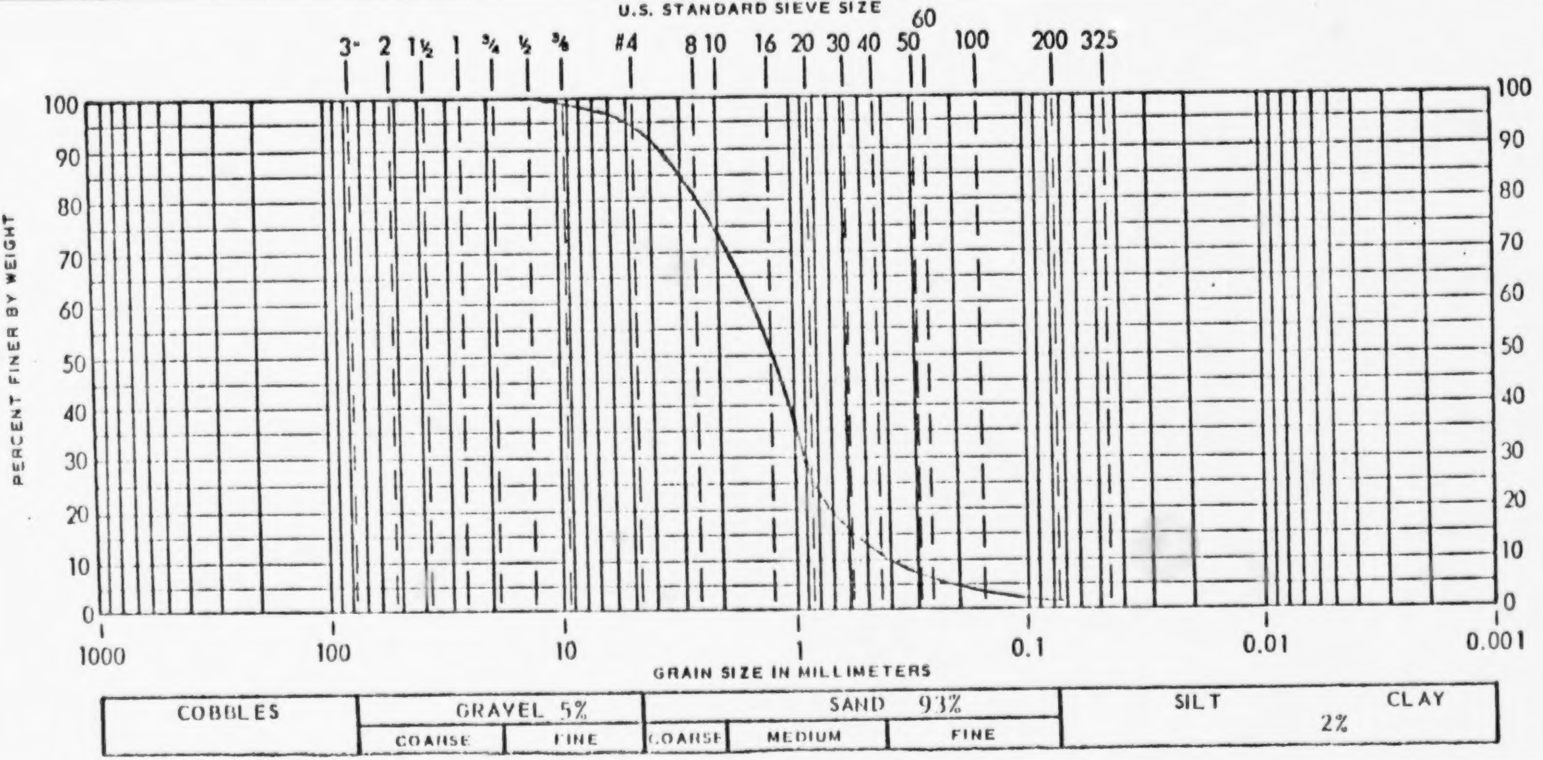
2A-34R

SOIL CLASSIFICATION SHEET



PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill
BORING NO. 6-1
SAMPLE NO. S3
DEPTH 9.0'-11.0'
CLASSIFICATION "SP"
Poorly graded "SAND"

NATURAL % MOISTURE 2.7
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Black
REMARKS "U.S.C.S."

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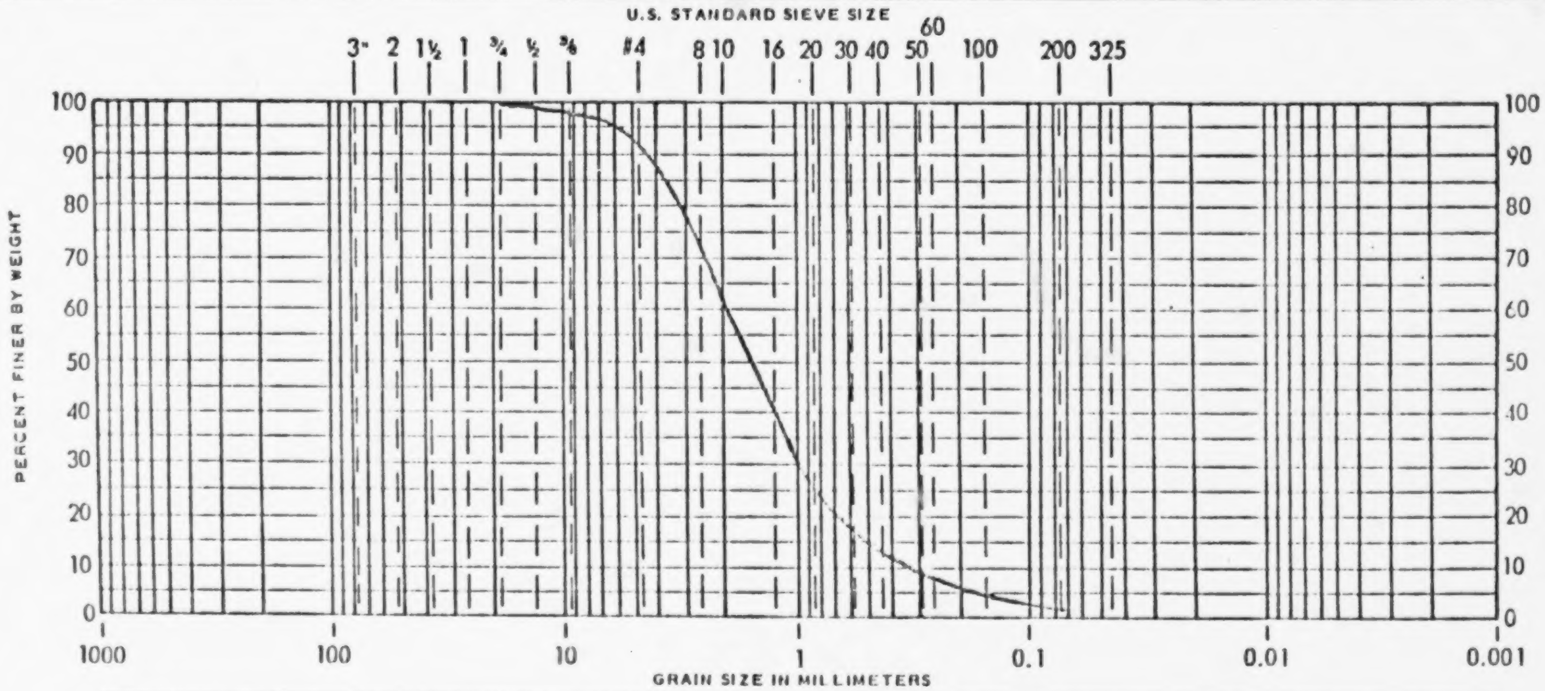
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 8%		SAND 89%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	3%	

PROJECT Arthur D. Little Powerton Site #8, Tazewell City, Ill
BORING NO. 6-1
SAMPLE NO. T2
DEPTH 22.0'-24.0'
CLASSIFICATION "SW"
Well Graded "SAND"

NATURAL % MOISTURE 8.1
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Black
REMARKS "U.S.C.S."

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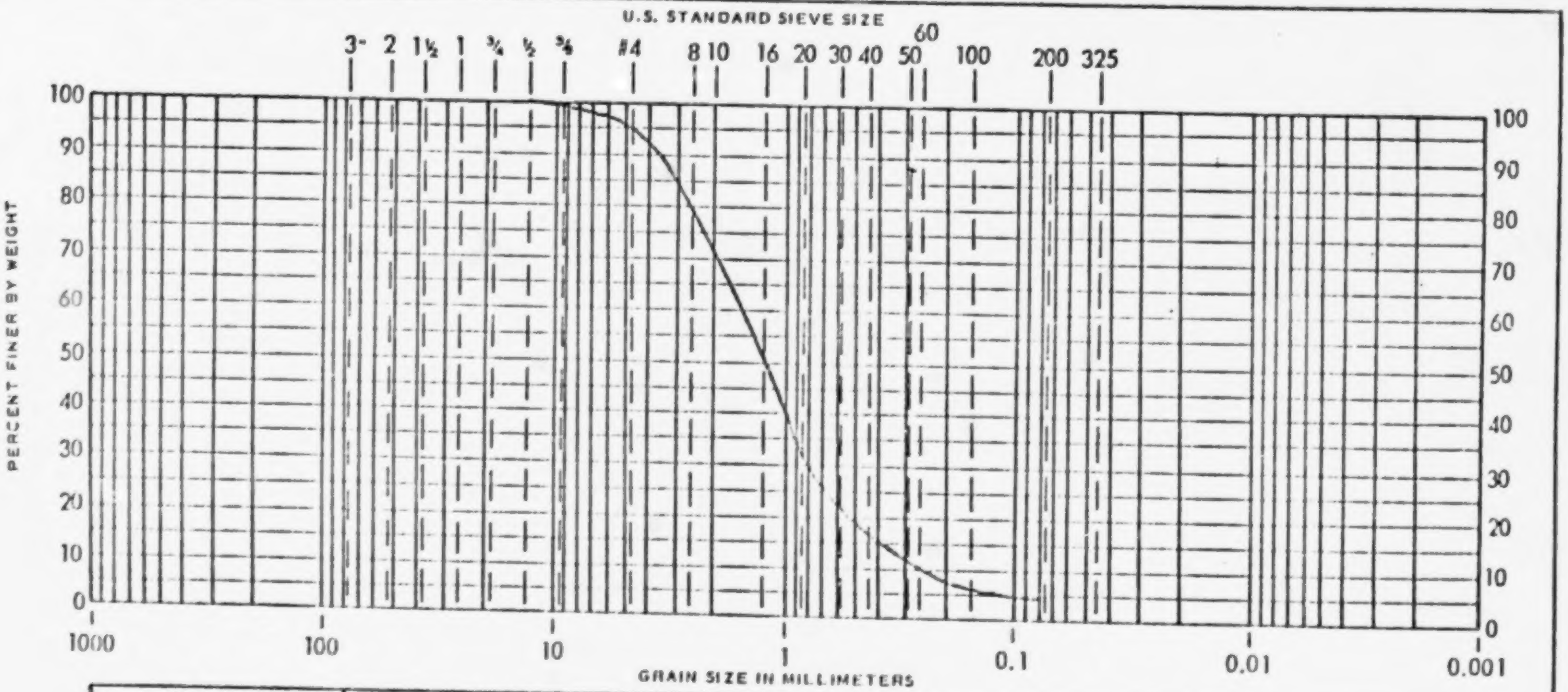
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 5%		SAND 90%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	5%	

PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill.
BORING NO. 6-1
SAMPLE NO. S8
DEPTH 30.0'-32.5'
CLASSIFICATION "SP"
Poorly graded "SAND"

NATURAL % MOISTURE 2.9
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Black
REMARKS "U.S.C.S."

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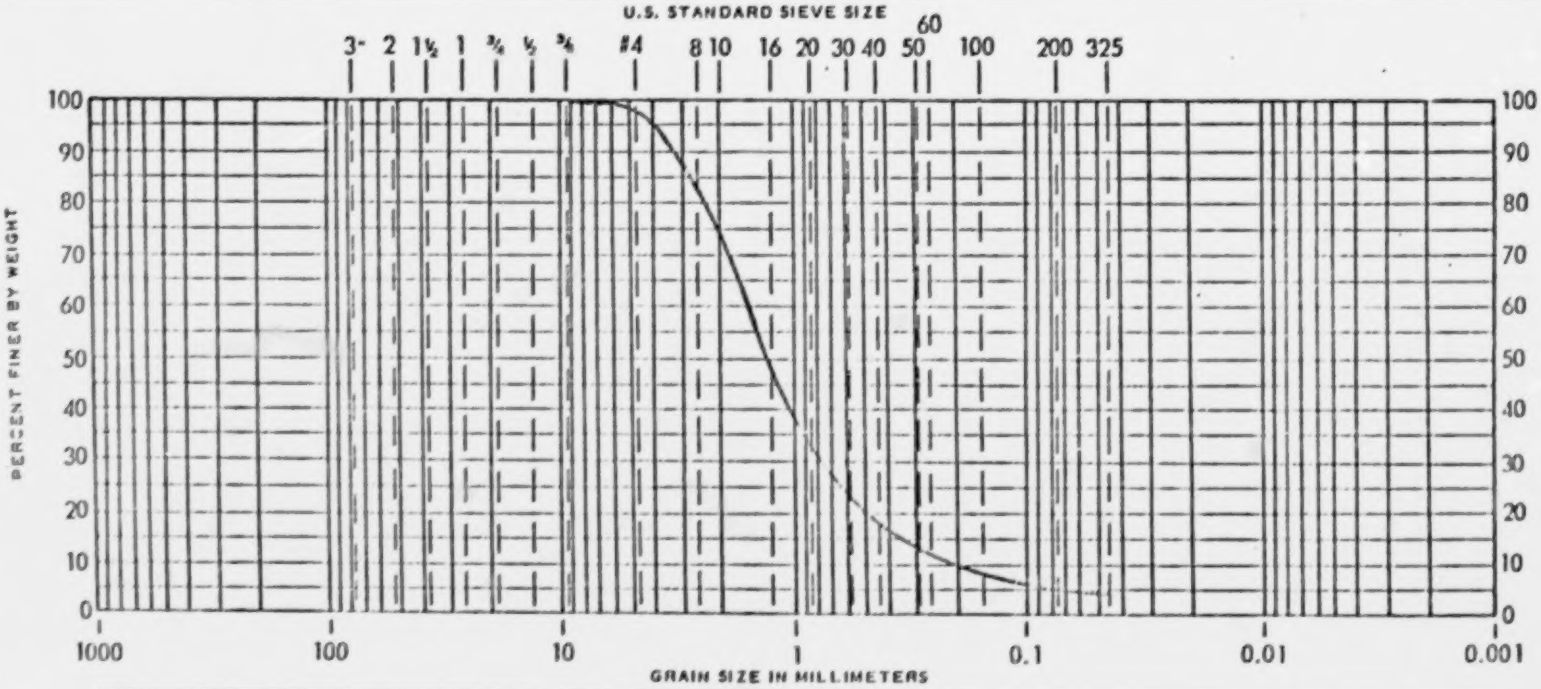
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 93%			SILT 6% CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

PROJECT Arthur D. Little Powerton Site #8, Tazewell City, Ill.

BORING NO.	6-1
SAMPLE NO.	S9
DEPTH	32.0'-34.0'
CLASSIFICATION	"SP-SM" poorly graded, silty "SAND"

NATURAL % MOISTURE	11.5
LIQUID LIMIT	Visually
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Black/Brown
REMARKS	"U.S.C.S."

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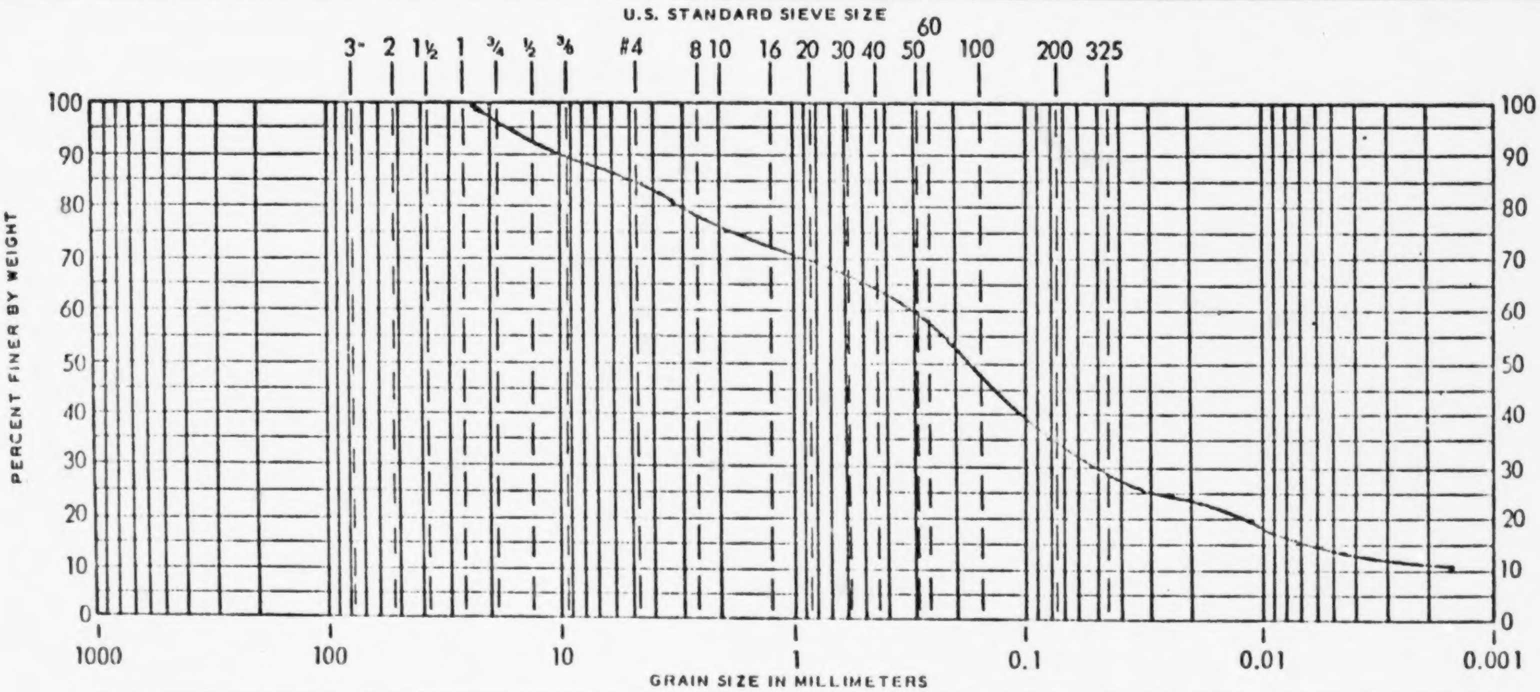
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 15%		SAND 50%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	20%	15%

PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill.
BORING NO. 6-2
SAMPLE NO. S1
DEPTH 0.0'-2.0'
CLASSIFICATION "SC" gravelly, clayey "SAND"

NATURAL % MOISTURE 8.1
LIQUID LIMIT 22
PLASTIC LIMIT 14
PLASTICITY INDEX 8
COLOR Red-Brown
REMARKS "U.S.C.S."

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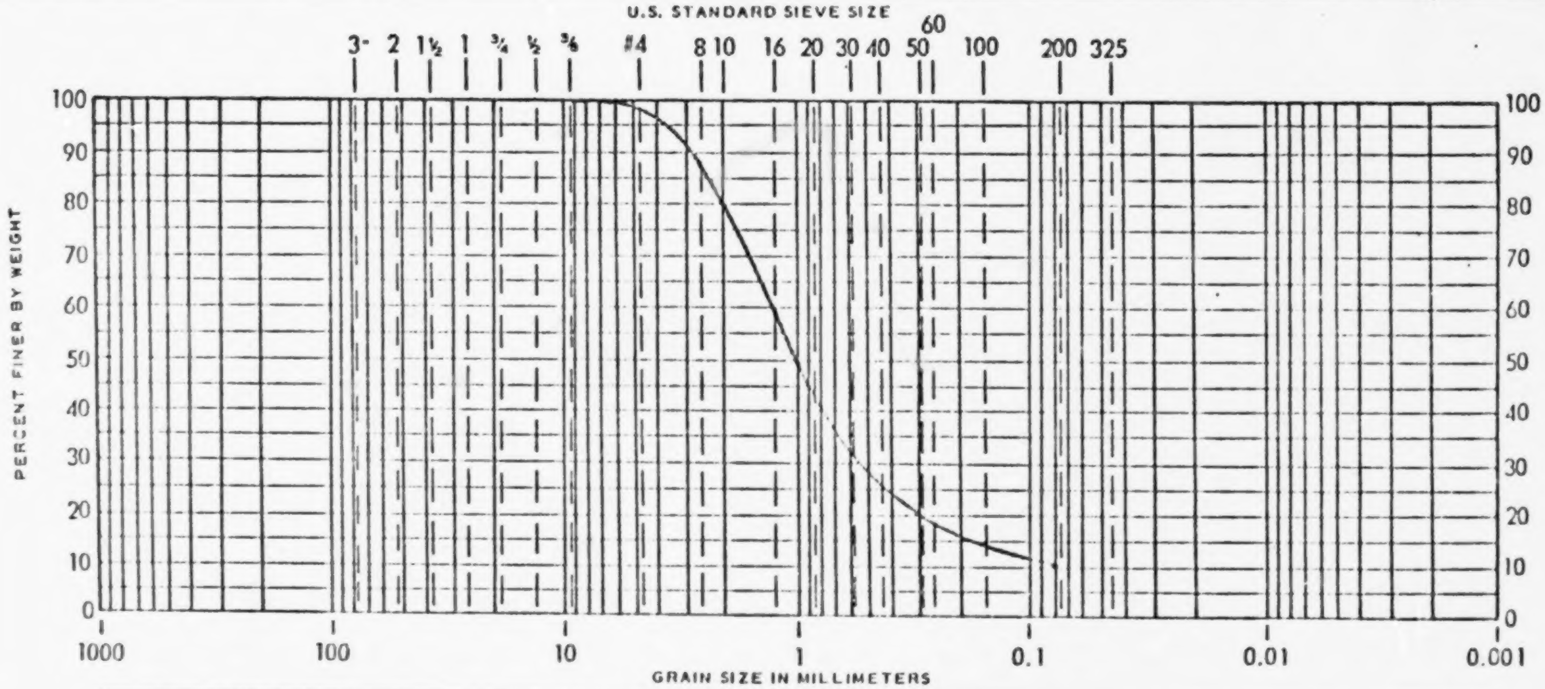
2A 34R

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 87%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	12%	

PROJECT Arthur D. Little Powerton Site #8, Tazewell City, Ill.
BORING NO. 6-2
SAMPLE NO. S2
DEPTH 2.0'-4.0'
CLASSIFICATION "SM" Silty SAND

NATURAL % MOISTURE ---
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Gray
REMARKS "U.S.C.S."

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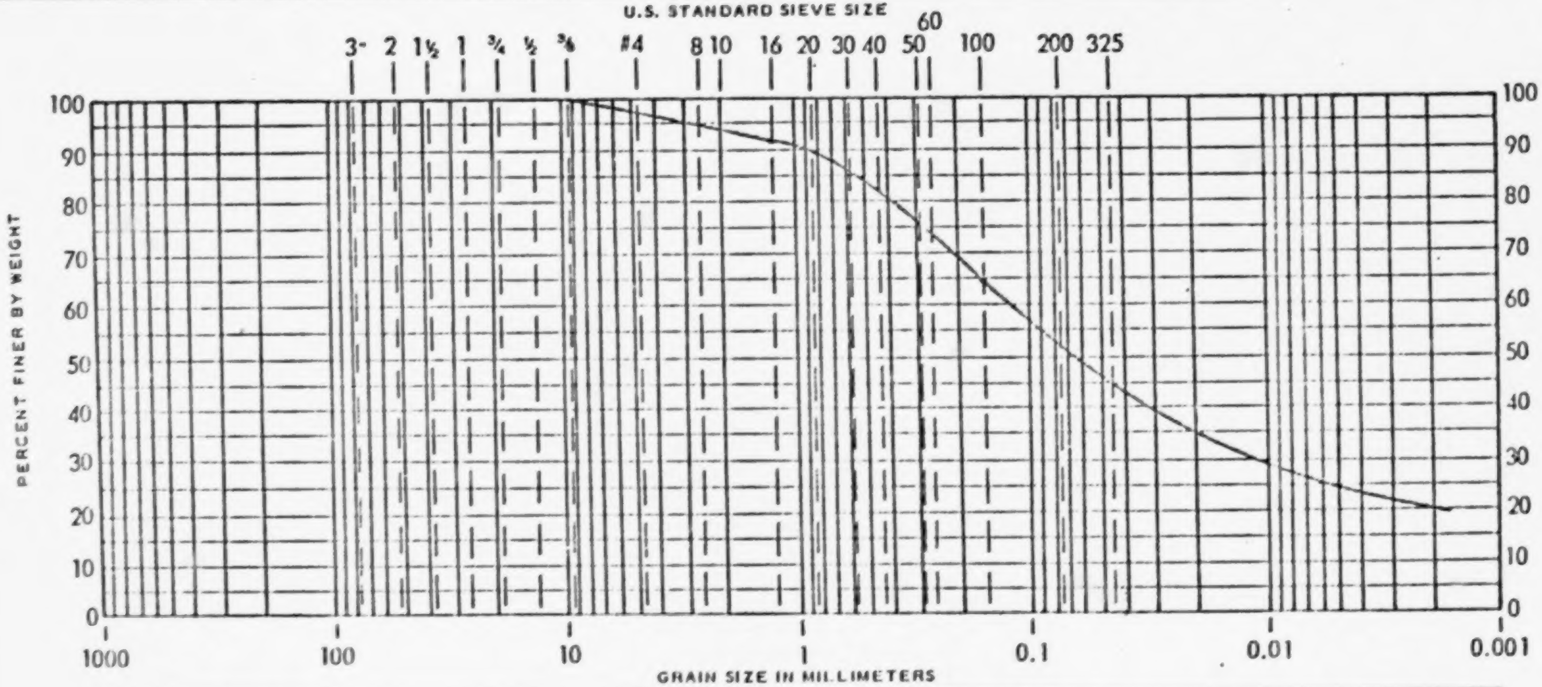
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 2%		SAND 44%			SILT 29%	CLAY 25%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little Powerton Site #8, Tazewell City, Ill
BORING NO. 6-2
SAMPLE NO. S2
DEPTH 2.0'-4.0'
CLASSIFICATION "ML-CL"
Sandy, Clayey "SILT"

NATURAL % MOISTURE ---
LIQUID LIMIT 25
PLASTIC LIMIT 21
PLASTICITY INDEX 4
COLOR Brown
REMARKS "U.S.C.S."

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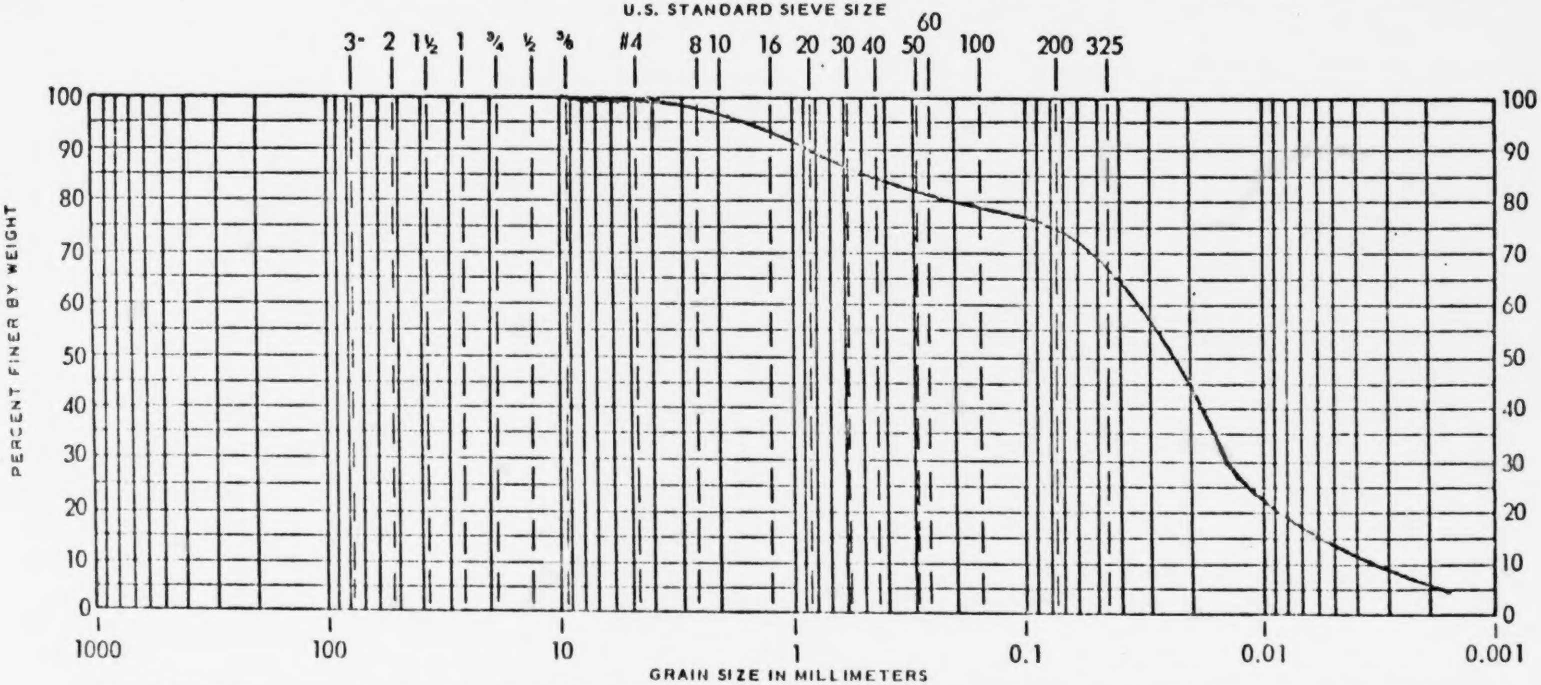
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 24%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	61%	14%

PROJECT Arthur D. Little Powerton Site #8, Tazewell City, Ill

BORING NO. 6-2

SAMPLE NO. U1

DEPTH 4.0'-6.0'

CLASSIFICATION "ML"
Sandy "SILT"

NATURAL % MOISTURE 12.8

LIQUID LIMIT Tested

PLASTIC LIMIT Non

PLASTICITY INDEX Plastic

COLOR Brown/Black

REMARKS "U.S.C.S."

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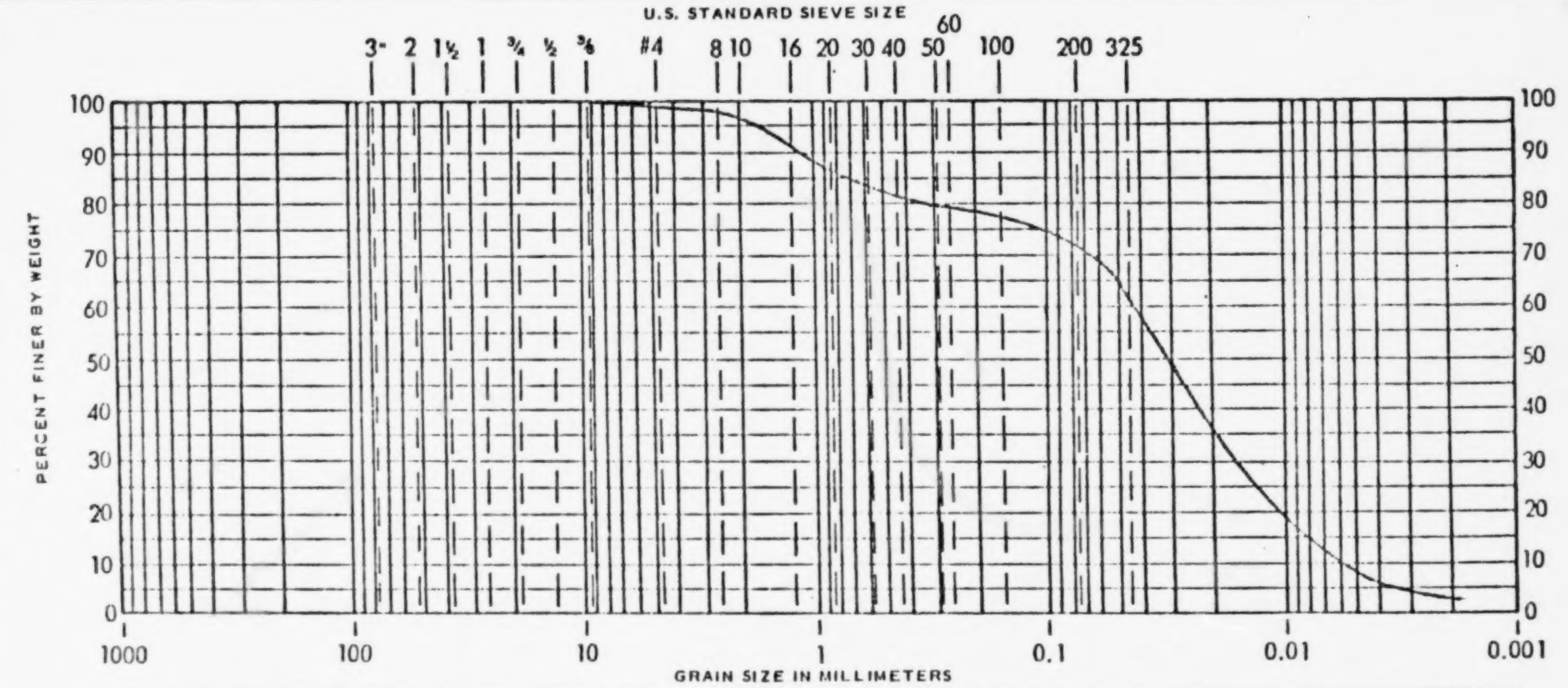
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 26%			SILT 64%	CLAY 9%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill
BORING NO. 6-2
SAMPLE NO. U2
DEPTH 14.0'-16.0'
CLASSIFICATION "ML"
Sandy "SILT"

NATURAL % MOISTURE 18.2
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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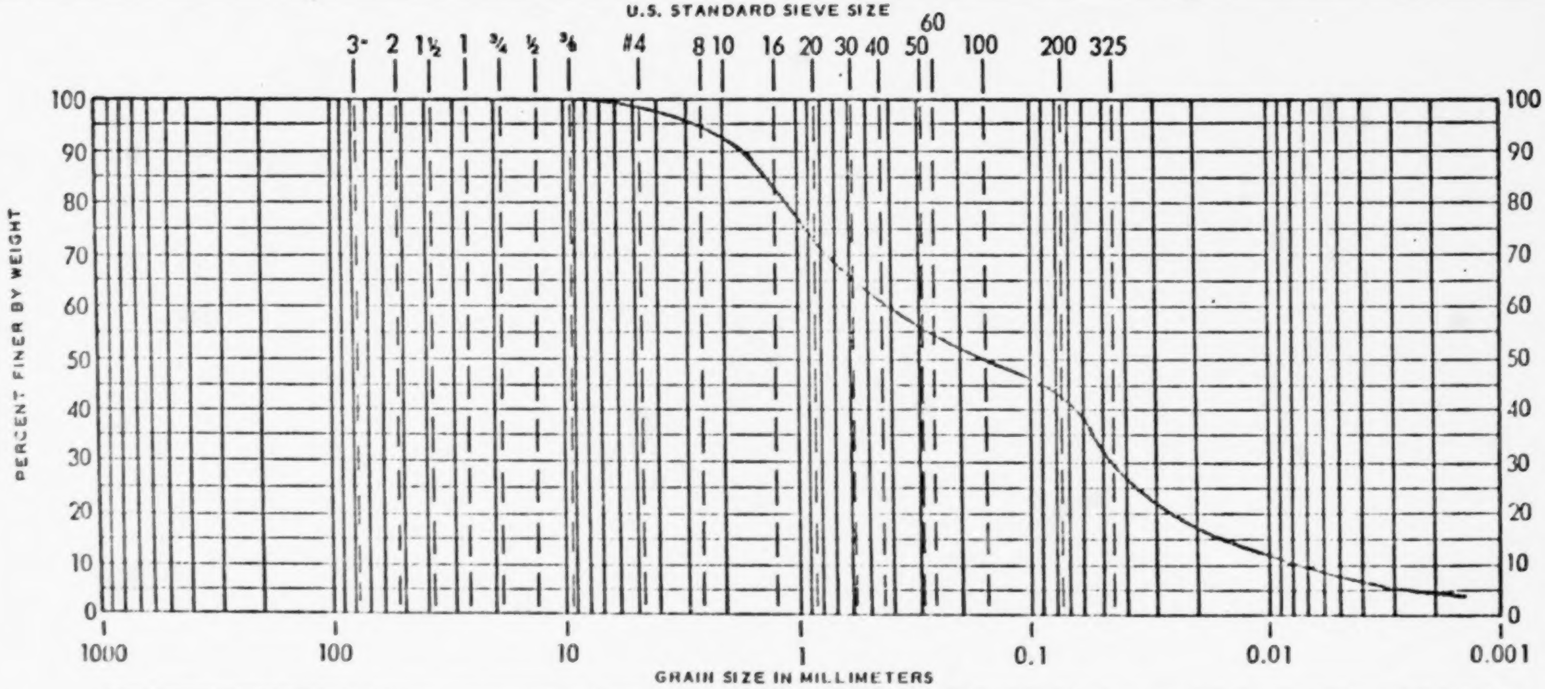
2A-34R

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 55%			SILT 36%	CLAY 8%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill.
BORING NO. 6-2
SAMPLE NO. S6
DEPTH 24.0'-26.0'
CLASSIFICATION "SM" Silty "SAND"

NATURAL % MOISTURE 9.4
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Black
REMARKS "U.S.C.S."

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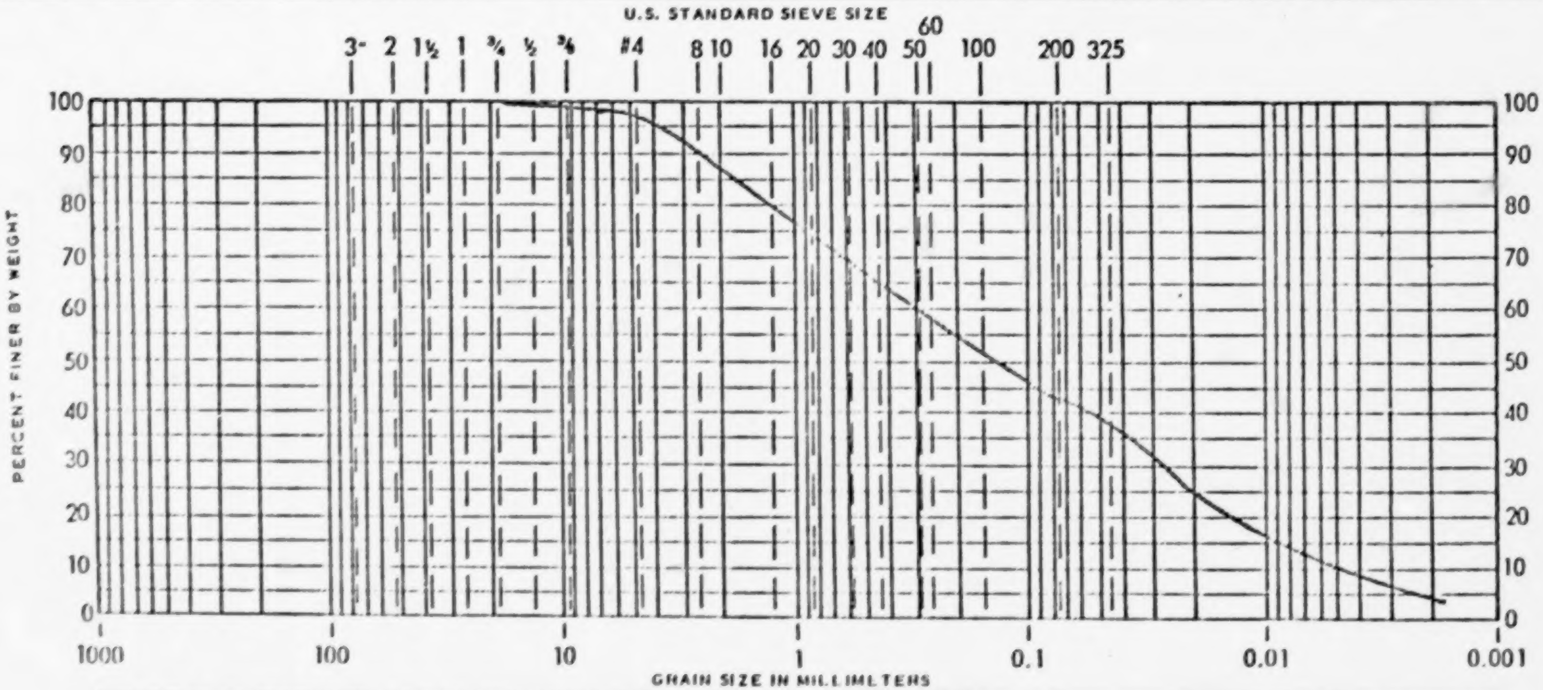
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 3%		SAND 54%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	33%	10%

PROJECT Arthur D. Little Powerton Site #8, Tazewell City, Ill
BORING NO. 6-2
SAMPLE NO. T1
DEPTH 27.0'-29.0'
CLASSIFICATION "SM"
Silty "SAND"

NATURAL % MOISTURE 9.7
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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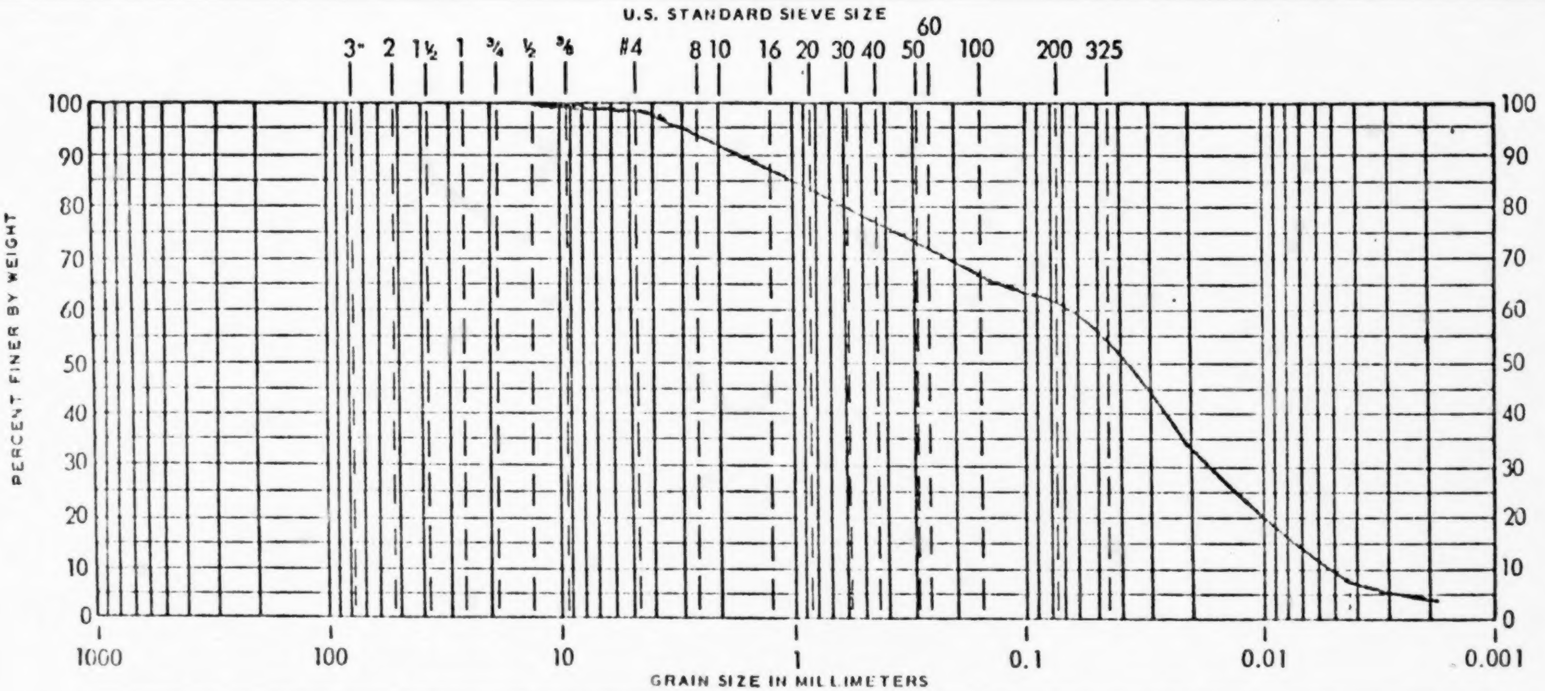
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 37%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	52%	10%

PROJECT Arthur D. Little Powerton Site #8, Tazewell City, Ill
BORING NO. 6-2
SAMPLE NO. T2
DEPTH 29.0'-31.0'
CLASSIFICATION "ML"
Sandy "SILT"

NATURAL % MOISTURE 12.3
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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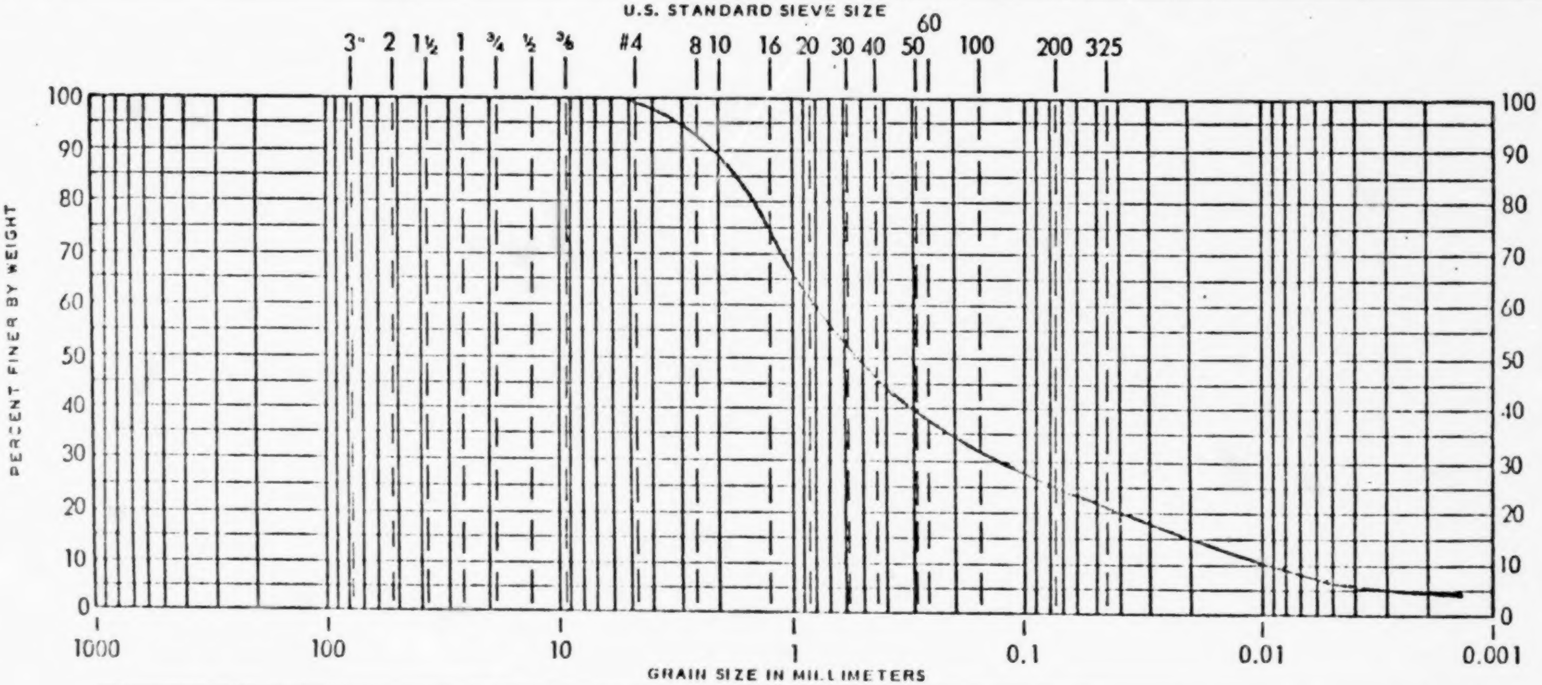
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 73%			SILT 19%	CLAY 7%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill
BORING NO. 6-2
SAMPLE NO. S8
DEPTH 31.2'-32.2'
CLASSIFICATION "SM" Silty "SAND"

NATURAL % MOISTURE 7.5
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Dark Brown
REMARKS "U.S.C.S."

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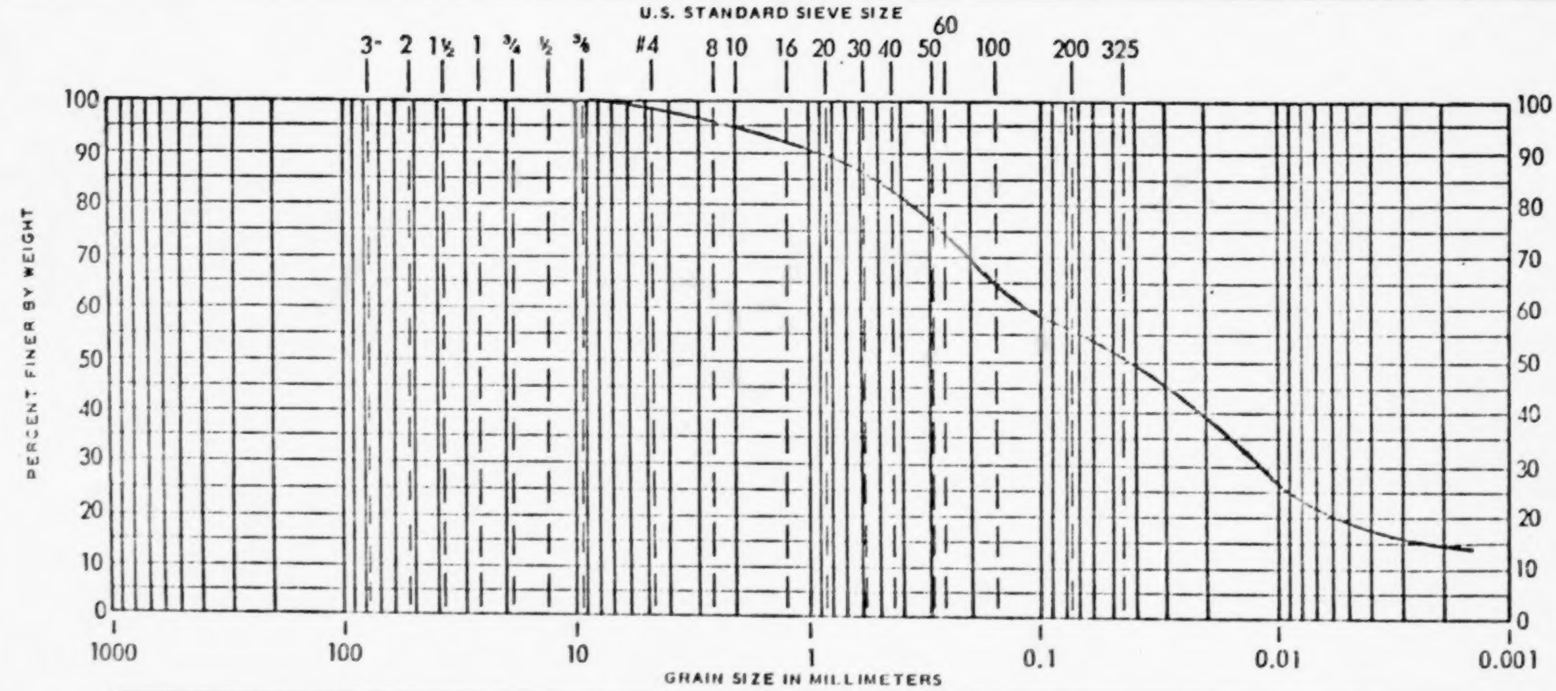
TESTING LABORATORIES, INC.

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 2%		SAND 43%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	36%	19%

PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill
BORING NO. 6-2
SAMPLE NO. S9
DEPTH 32.2'-33.2'
CLASSIFICATION "ML"
Silty, Fine "SAND"

NATURAL % MOISTURE 13.3
LIQUID LIMIT 17
PLASTIC LIMIT 15
PLASTICITY INDEX 2
COLOR Dark-Brown
REMARKS "U.S.C.S."

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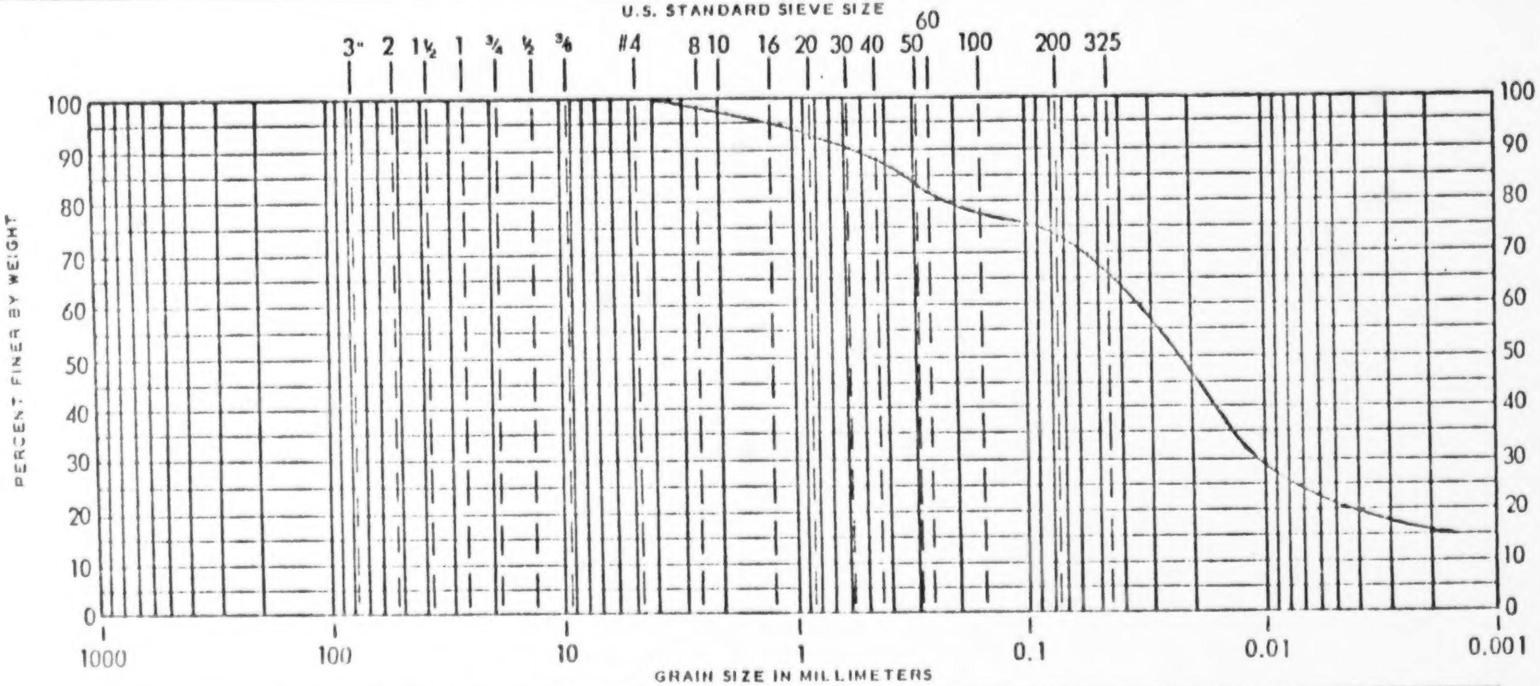
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL		SAND 25%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	55%	20%

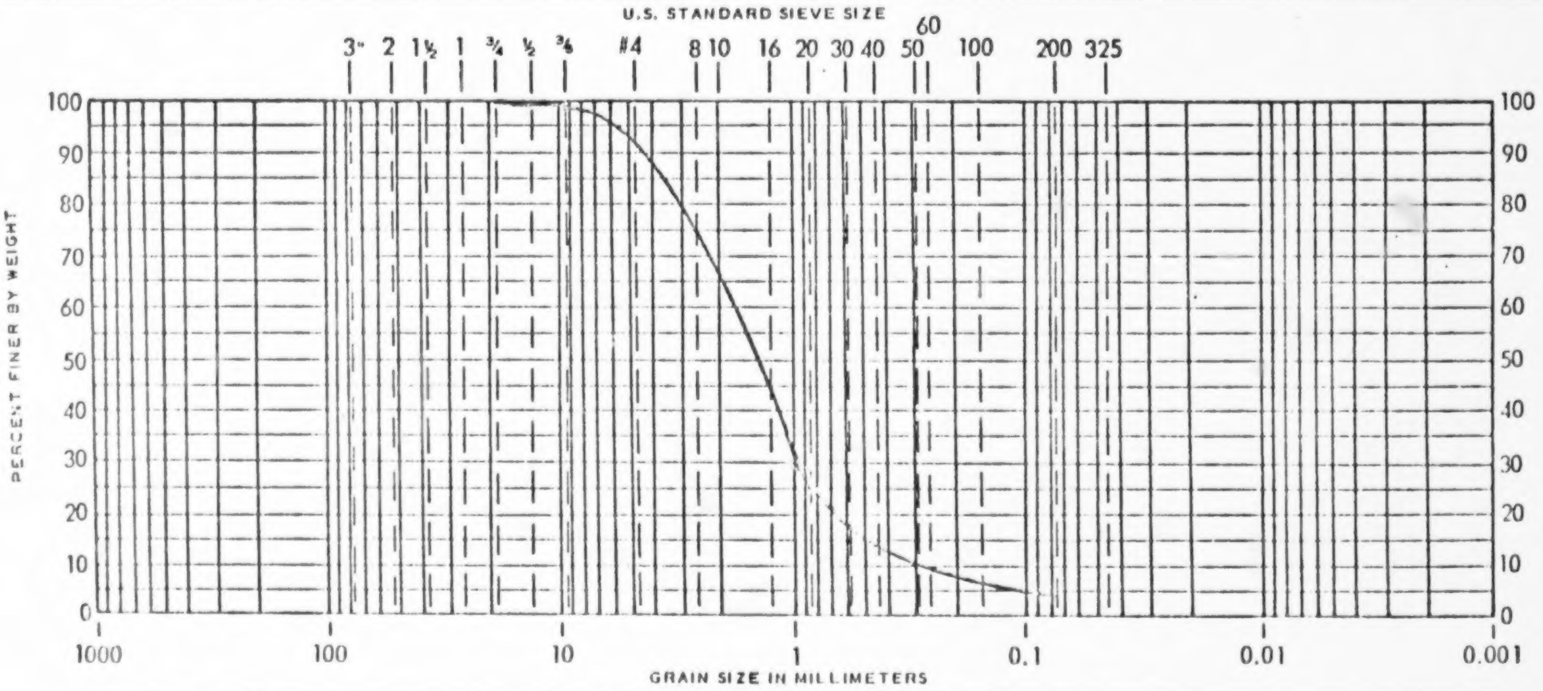
PROJECT Arthur D. Little Powerton Site #8, Tazewell City, Ill
BORING NO. 6-3
SAMPLE NO. S1
DEPTH 0.0'-2.0'
CLASSIFICATION "ML-CL"
Sandy, Clayey "SILT"

NATURAL % MOISTURE ---
LIQUID LIMIT 30
PLASTIC LIMIT 23
PLASTICITY INDEX 7
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A 14II

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 8%		SAND 87%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	5%	

PROJECT Arthur A. Little Powerton Site #8, Tazewell City, Ill.
BORING NO. 6-3
SAMPLE NO. T1
DEPTH 4.0'-6.0'
CLASSIFICATION "SW"
well graded "SAND"

NATURAL % MOISTURE 2.6
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Black
REMARKS "U.S.C.S."

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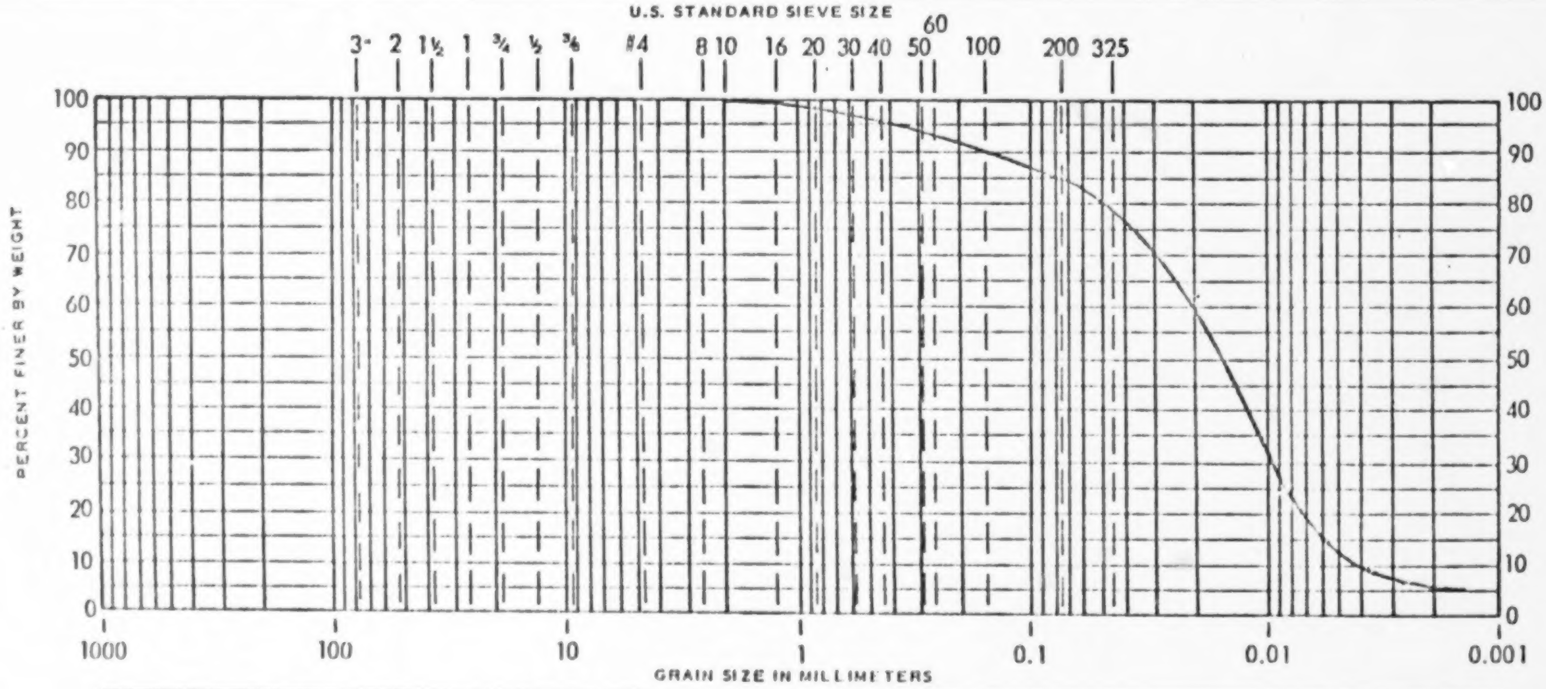
2A 34II

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL		SAND 15%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	72%	13%

PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill

BORING NO. 6-3

SAMPLE NO. S5

DEPTH 13.0'-15.0'

CLASSIFICATION "ML"
"SILT"

NATURAL % MOISTURE 23.7

LIQUID LIMIT Tested

PLASTIC LIMIT Non

PLASTICITY INDEX Plastic

COLOR Dark Brown

REMARKS "U.S.C.S."

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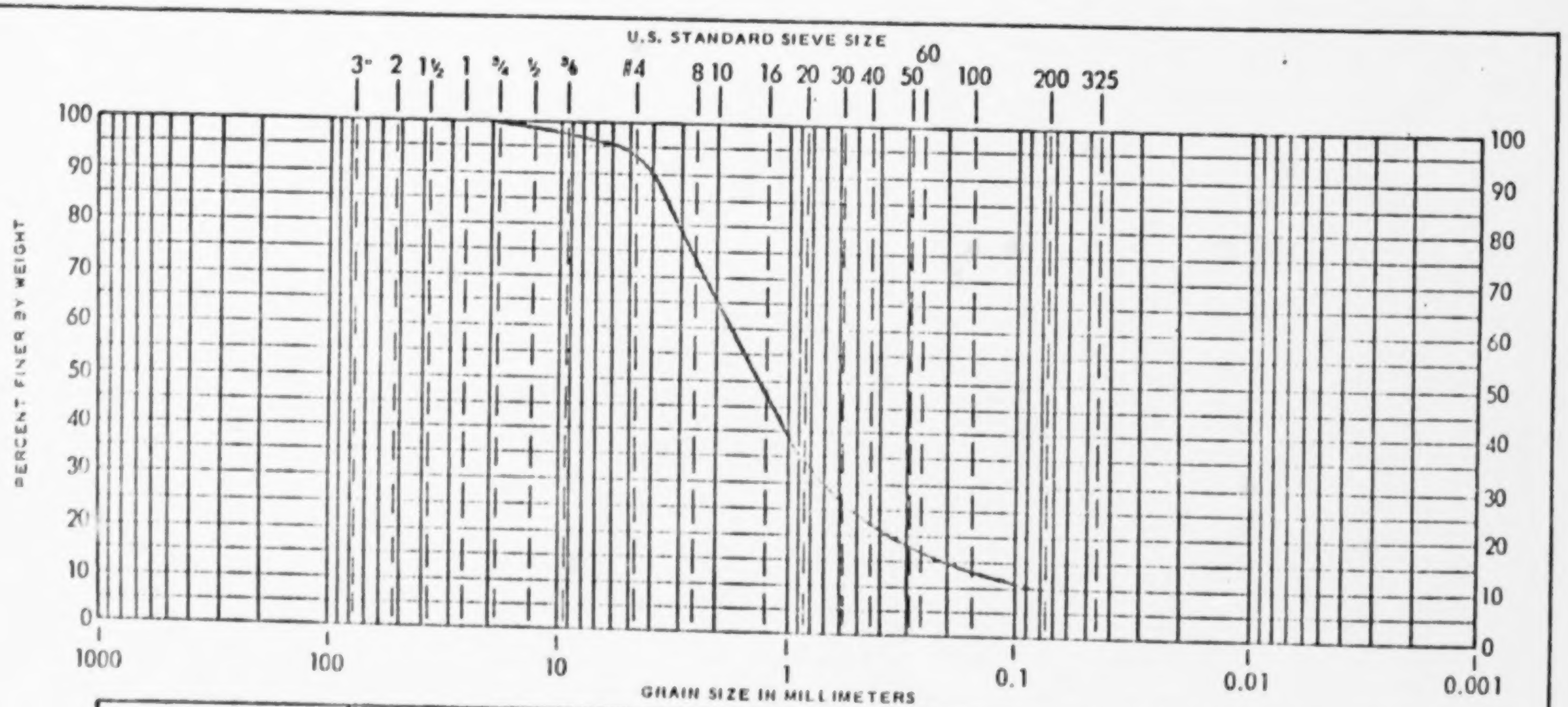

COBBLES	GRAVEL 6%		SAND 84%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	10%	

PROJECT	Arthur D. Little Powerton Site #8, Tazewell City, Ill.
BORING NO.	6-3
SAMPLE NO.	S6
DEPTH	15.0'-17.0'
CLASSIFICATION	"SP-SM" poorly graded, silty "SAND"

NATURAL % MOISTURE	17.9
LIQUID LIMIT	Visually
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Gray/Black
REMARKS	"U.S.C.S."

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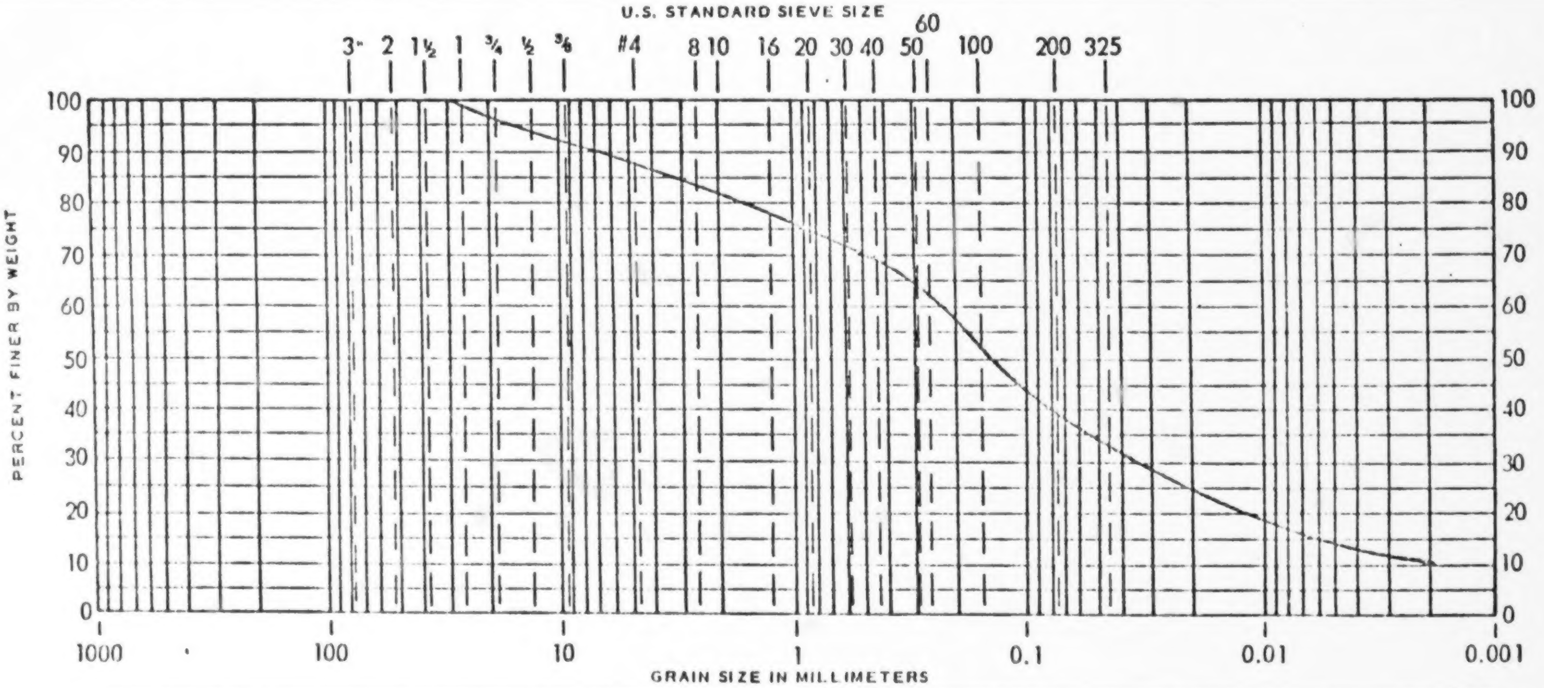
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 11%		SAND 49%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	25%	15%

PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill.
BORING NO. 6-9
SAMPLE NO. S1
DEPTH 0.0'-2.0'
CLASSIFICATION "SM"
Gravelly, Silty "SAND"

NATURAL % MOISTURE 8.6
LIQUID LIMIT 24
PLASTIC LIMIT 21
PLASTICITY INDEX 3
COLOR Brown
REMARKS "U.S.C.S."

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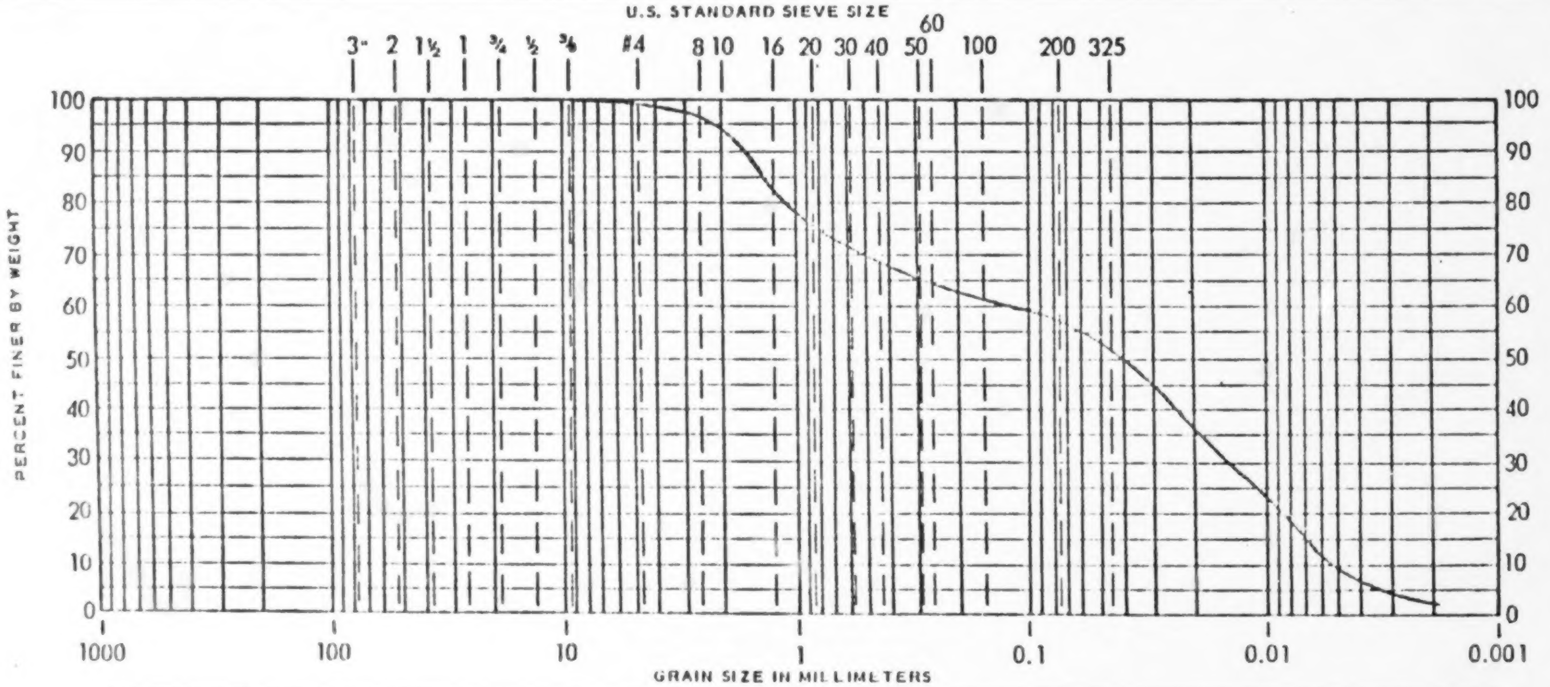
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 41%			SILT 49%	CLAY 9%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little, Powerton Site #8, Tazewell City, Ill.

BORING NO.	6-9
SAMPLE NO.	S3
DEPTH	9.0'-11.0'
CLASSIFICATION	"ML" Sandy "SILT"

NATURAL % MOISTURE	13.9
LIQUID LIMIT	Tested
PLASTIC LIMIT	Non
PLASTICITY INDEX	Plastic
COLOR	Brown
REMARKS	"U.S.C.S."

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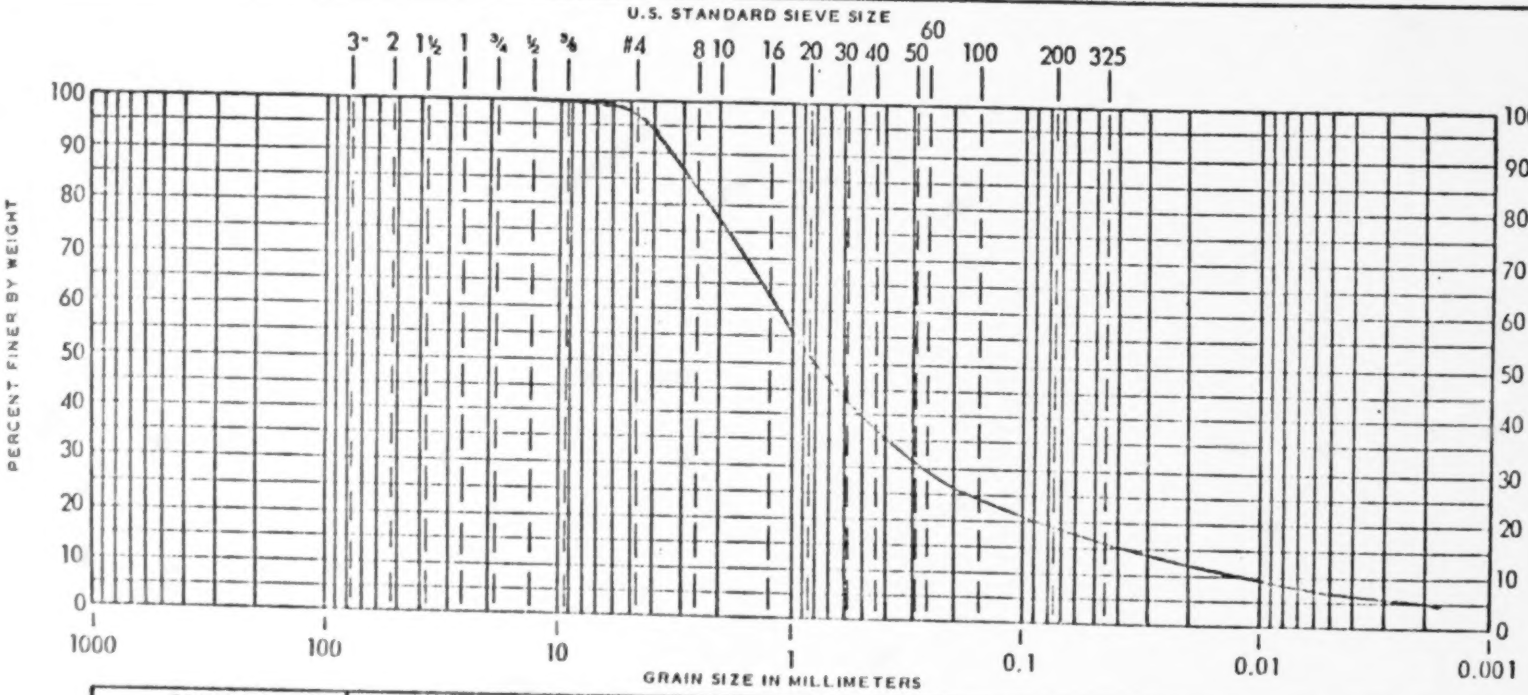
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 3%		SAND 79%			SILT 11%	CLAY 7%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT Arthur D. Little Powerton Site #8, Tazewell City, Ill.
BORING NO. 6-9
SAMPLE NO. S7
DEPTH 30.0'-31.0'
CLASSIFICATION "SM" Silty "SAND"

NATURAL % MOISTURE 9.3
LIQUID LIMIT Tested
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
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2A-3411

LABORAT SUMMARY SHEET

Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Page 1 of 4

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
6-1	S1	0.0-2.0		30	17	13	11.7			"SC"
	S2	2.0-4.0					5.4			
	S3	9.0-11.0		Visually Non Plastic			2.7			"SP"
	S4	20.0-22.0					2.4*			
	S5	24.0-26.0					4.0*			
	S6	26.0-28.0					3.1*			
	S7	28.0-30.0					3.4*			
	S8	30.0-32.0		Visually Non Plastic			2.9			"SP"
	S9	32.0-34.0		Visually Non Plastic			11.5*			"SP-SM"
	S10	34.0-36.0					14.5*			
	S11	36.0-38.0					18.1*			
	S12	38.0-40.0					Saturated			
6-2	S1	0.0-2.0		22	14	8	8.1			"SC"
	S2	2.0-4.0		25	21	4	---			"ML"CL"
	S2	2.0-4.0		Visually Non Plastic			---			"SM"
	S3	9.0-11.0					12.9*			
	S4	16.0-18.0					22.3			
	S5	19.0-21.0					20.0			
	S6	24.0-26.0		Tested Non Plastic			9.4			"SM"
	S7	29.2-31.2					3.4			
	S8	31.2-32.2		Tested Non Plastic			7.5			"SM"
	S9	32.2-33.2		17	15	2	13.3			"ML"
	S10	33.2-35.2					19.3			
	S11	35.2-37.2					26.1			
	S12	37.2-39.2					16.8			
6-3	S1	0.0-2.0		30	23	7	---			"ML-CL"
	S2	2.0-4.0					9.1*			
	S3	9.0-11.0					9.5*			
	S4	11.0-13.0					3.4*			
	S5	13.0-15.0		Tested Non Plastic			23.7			"ML"
	S6	15.0-17.0		Visually Non Plastic			17.9			"SP-SM"

*140°F

LABORA Y SUMMARY SHEET

Arthur D Little, Powerton Site #8, Tazewell City, Illinois

Page 2 of 4

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plas-ticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S Soil Classi-ficatio
	S7	17.0-19.0					25.3			
	S8	19.0-21.0					27.0			
	S9	21.0-23.0					25.1			
	S10	24.0-26.0					4.5			
6-4	S1	0.0-2.0					23.1			
	S2	2.0-4.0					26.1			
	S3	4.0-6.0					26.8			
	S4	6.0-8.0					29.6			
	S5	8.0-10.0					23.0			
	S6	10.0-12.0					25.2			
	S7	12.0-14.0					15.8			
	S8	14.0-16.0					25.6			
	S9	16.0-18.0					0.3			
	S10	18.0-20.0					9.3			
	S11	20.0-22.0					12.6			
	S12	22.0-24.0					9.0			
	S13	30.0-32.0					1.8			
	S14	35.0-37.0					15.1			
	S15	45.0-47.0					14.4			
	S16	66.5-68.5					16.4			
6-5	S1	0.0-2.0					22.8			
	S2	2.0-4.0					30.9			
	S3	4.0-6.0					25.8			
	S4	6.0-8.0					23.7			
	S5	8.0-10.0					4.7			
	S6	10.0-12.0					7.7			
	S7	12.0-14.0					4.3			
	S8	14.0-16.0					4.1			
	S9	19.0-21.0					6.5			
	S10	24.0-26.0					19.9			
	S11	29.0-31.0					16.7			
	S12	34.0-36.0					14.9			

LABORAT SUMMARY SHEET

Arthur D. Little, Powerton Site #8 Tazewell City, Illinois

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plas-ticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C. Soil Classi ficati
6-6	S1	0.0-2.0					11.0			
	S2	2.0-4.0					5.4			
	S3	4.0-6.0					8.7			
	S4	6.0-8.0					4.8			
	S5	8.0-10.0					3.7			
	S6	10.0-12.0					3.9			
	S7	12.0-14.0					3.7			
	S8	14.0-16.0					4.0			
	S9	16.0-18.0					3.4			
	S10	18.0-20.0					4.1			
	S11	21.0-23.0					3.6			
	S12	23.0-25.0					1.8			
	S13	26.0-28.0					1.6			
	S14	28.0-30.0					5.2			
	S15	31.0-33.0					4.2			
	S16	33.0-35.0					1.5			
	S17	36.0-38.0					11.8			
	S18	38.0-40.0					Saturated			
	S19	41.0-43.0					11.4			
	S20	49.0-51.0					17.9			
	S21	54.0-56.0					9.7			
	S22	64.0-66.0					9.1			
	S23	74.0-76.0					11.2			
	S24	94.3-96.3					17.3			
6-9	S1	0.0-2.0		24	21	3	8.6			"SM
	S2	2.0-4.0					11.0			
	S3	9.0-11.0		Tested Non Plastic			13.9			"ML
	S4	20.0-22.0					6.8*			
	S5	25.0-27.0					18.5			
	S6	27.0-29.0					21.6			
	S7	30.0-31.0		Tested Non Plastic			9.3			"SM

*140°F

LABORAT SUMMARY SHEET

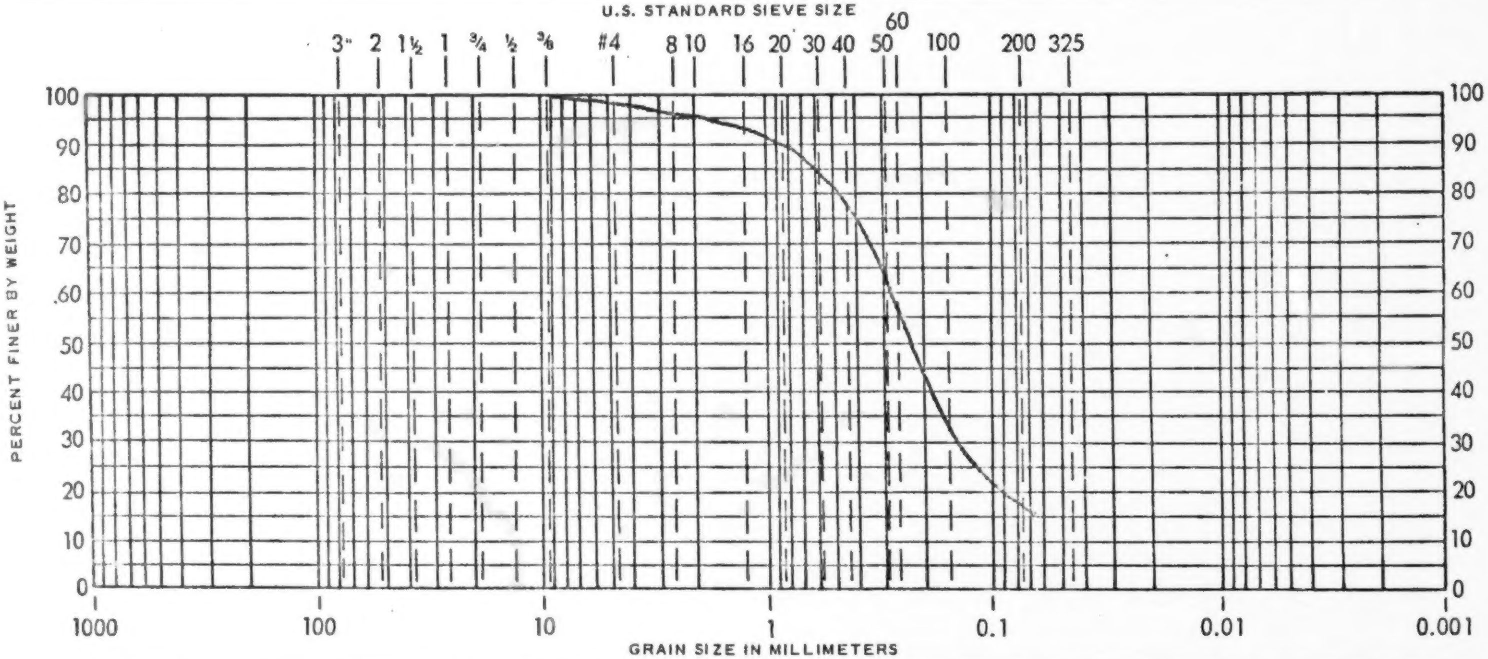
Arthur D. Little, Powerton Site #8, Tazewell City, Illinois

Page 4 of 4

Boring No.	Sample No.	Depth (Feet)	Material	Liquid Limits	Plastic Limits	Plasticity Index	Moisture Content (%)	Dry Unit Weight (pcf)	Unconfined Compressive Strength (psf)	U.S.C.S. Soil Classification
	S8	31.0-33.0					15.1			
	S9	33.0-35.0					16.2			
	S10	35.0-37.0					10.3			
	S11	37.0-39.0					11.2			
	S12	39.0-41.0					8.0			
6-9A	S1	39.0-31.0					9.3			
6-1	T1	4.0-6.0								
	T2	22.0-24.0		Visually Non Plastic			8.1*	95.0		"SW"
6-2	U1	4.0-6.0		Tested Non Plastic			12.8*	103.1		"ML"
	U2	14.0-16.0		Tested Non Plastic			18.2*			"ML"
	T1	27.0-29.0		Tested Non Plastic			9.7*			"SM"
	T2	29.0-3 0		Tested Non Plastic			12.3	123.9		"ML"
6-3	T1	4.0-6.0		Visually Non Plastic			3.6*	90.5		"SW"

*140°F

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 2%		SAND 82%			SILT CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	16%

PROJECT A.D.L. Powerton Power Plant
BORING NO. 6-2
SAMPLE NO. S-10
DEPTH 33.2'-35.2'
CLASSIFICATION "SM" Silty "SAND"

NATURAL % MOISTURE Saturated
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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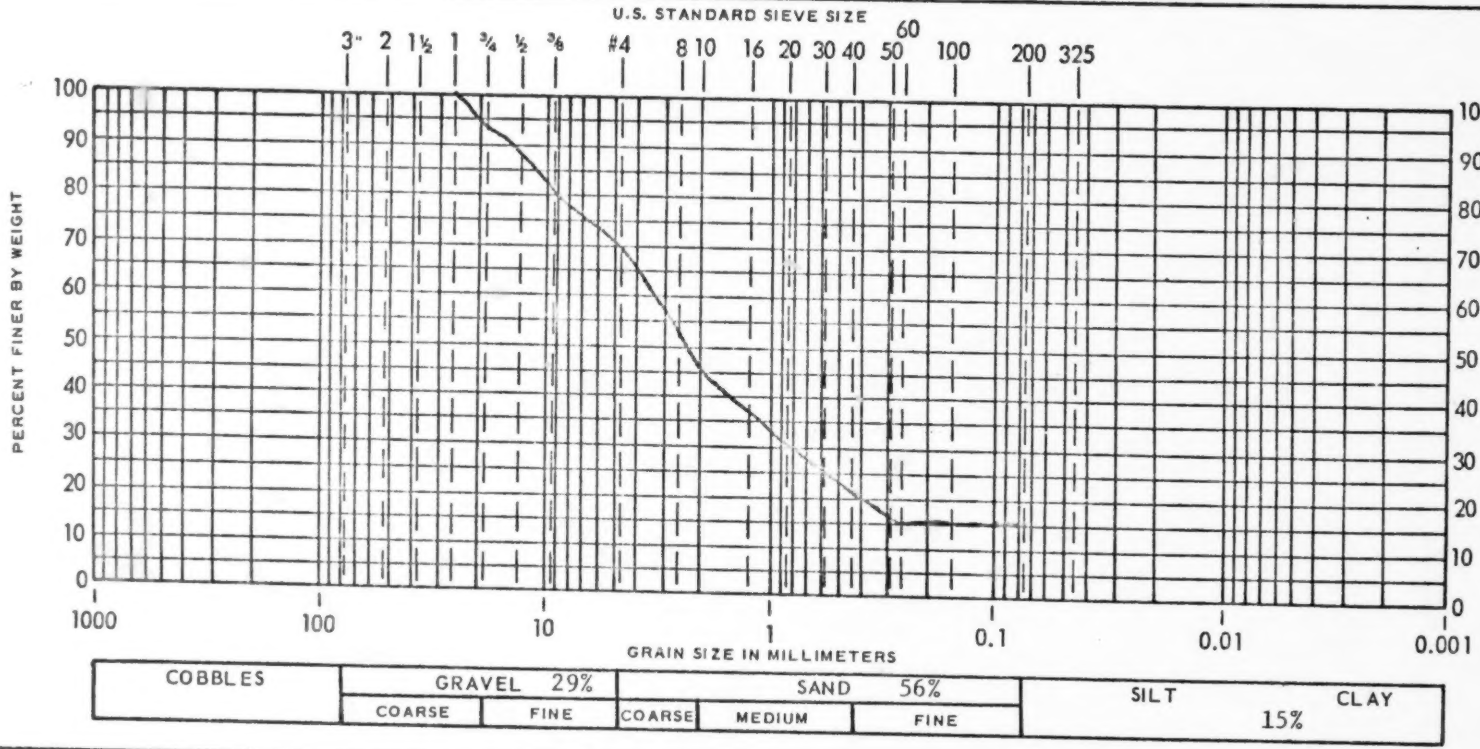
2A-34R

SOIL CLASSIFICATION SHEET



PROJECT A.D.L. Powerton Power Plant
BORING NO. 6-3
SAMPLE NO. S10
DEPTH 24.0'-26.0'
CLASSIFICATION "SM" Silty "SAND"

NATURAL % MOISTURE 5.5
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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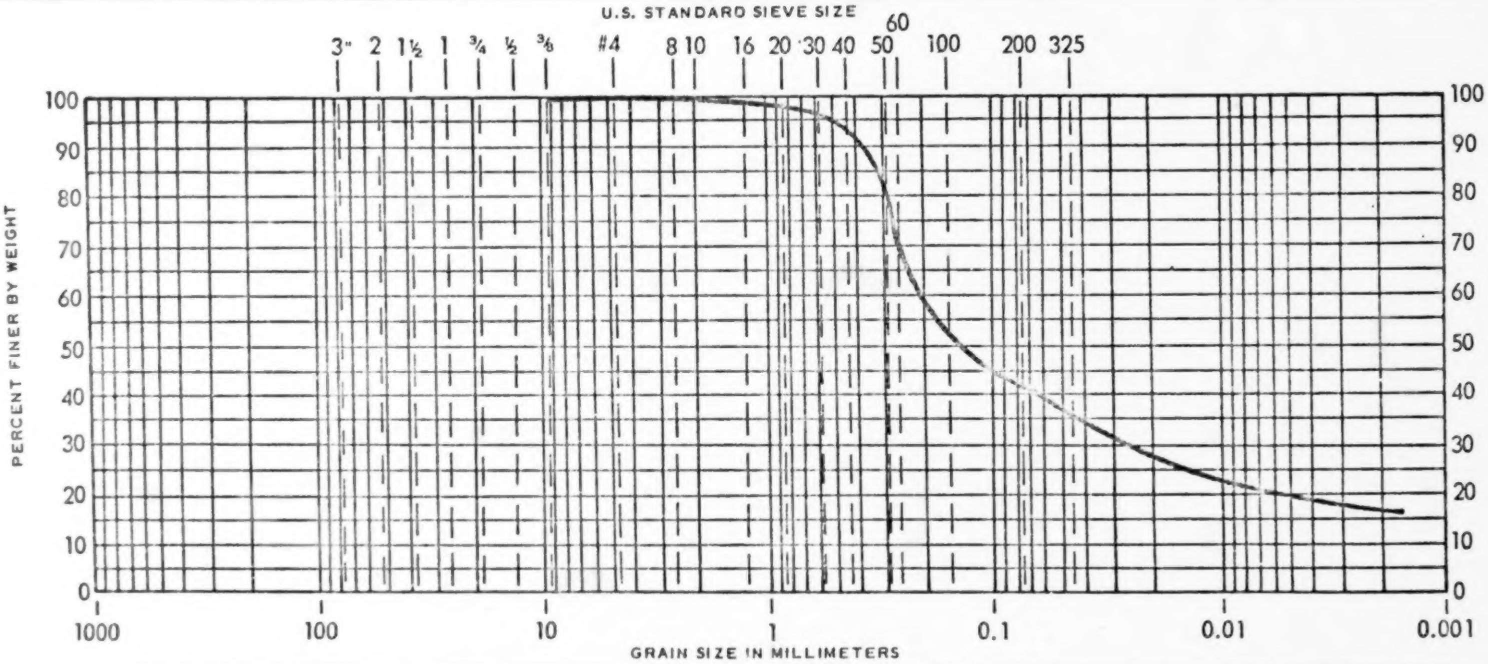
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 1%		SAND 58%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	20%	20%

PROJECT A.D.L. Powerton Power Plant
BORING NO. 6-4
SAMPLE NO. S4
DEPTH 6.0'-8.0'
CLASSIFICATION "SC" Clayey "SAND"

NATURAL % MOISTURE 23.6
LIQUID LIMIT 26
PLASTIC LIMIT 15
PLASTICITY INDEX 11
COLOR Gray/Brown
REMARKS "U.S.C.S."

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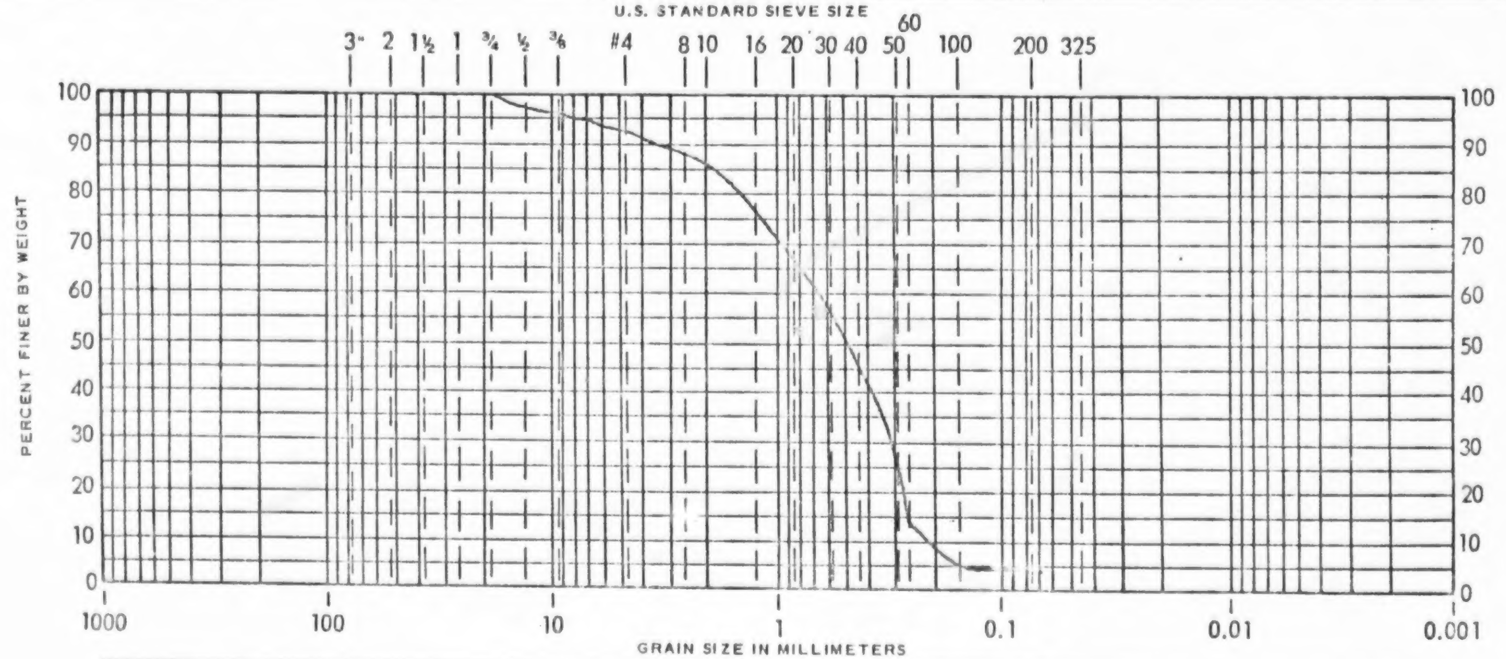
SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 7%		SAND 89%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	4%	

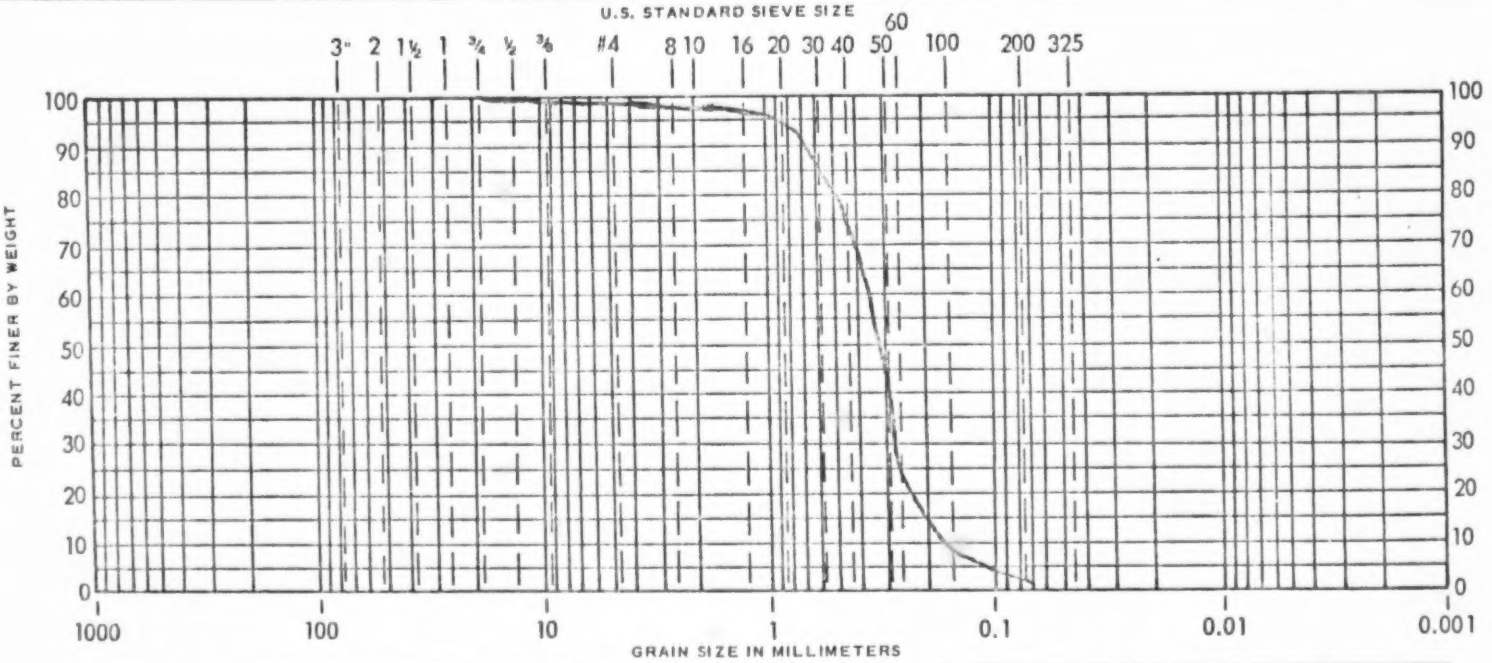
PROJECT A.D.L. Powerton Power Plant
BORING NO. 6-4
SAMPLE NO. S-12
DEPTH 22.0'-24.0'
CLASSIFICATION "SP"
Poorly Graded "SAND"

NATURAL % MOISTURE 7.9
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A-34R

SOIL CLASSIFICATION SHEET



COBBLES	GRAVEL 2%		SAND 96%			SILT	CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	2%	

PROJECT A.D.L. Powerton Power Plant
BORING NO. 6-6
SAMPLE NO. S19
DEPTH 41.0'-43.0'
CLASSIFICATION "SP"
poorly graded "SAND"

NATURAL % MOISTURE 15.0
LIQUID LIMIT Visually
PLASTIC LIMIT Non
PLASTICITY INDEX Plastic
COLOR Brown
REMARKS "U.S.C.S."

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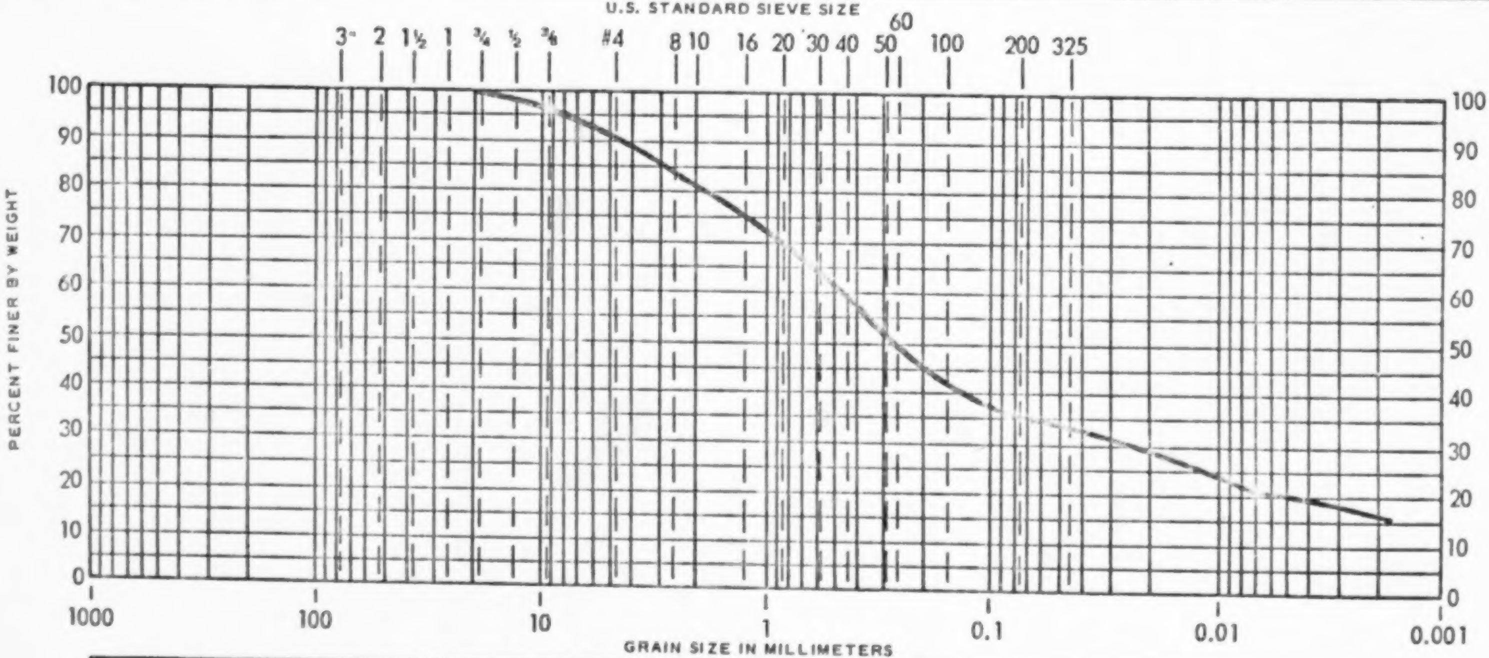

COBBLES	GRAVEL 10%		SAND 55%			SILT 15%	CLAY 20%
	COARSE	FINE	COARSE	MEDIUM	FINE		

PROJECT A.D.L. Powerton Power Plant
BORING NO. 6-9
SAMPLE NO. S9
DEPTH 33.0'-35.0'
CLASSIFICATION "SC"
Gravelly, clayey "SAND"

NATURAL % MOISTURE 16.9
LIQUID LIMIT 38
PLASTIC LIMIT 21
PLASTICITY INDEX 17
COLOR Brown
REMARKS "U.S.C.S."

BOWSER-MORNER
TESTING LABORATORIES, INC.

2A-34R